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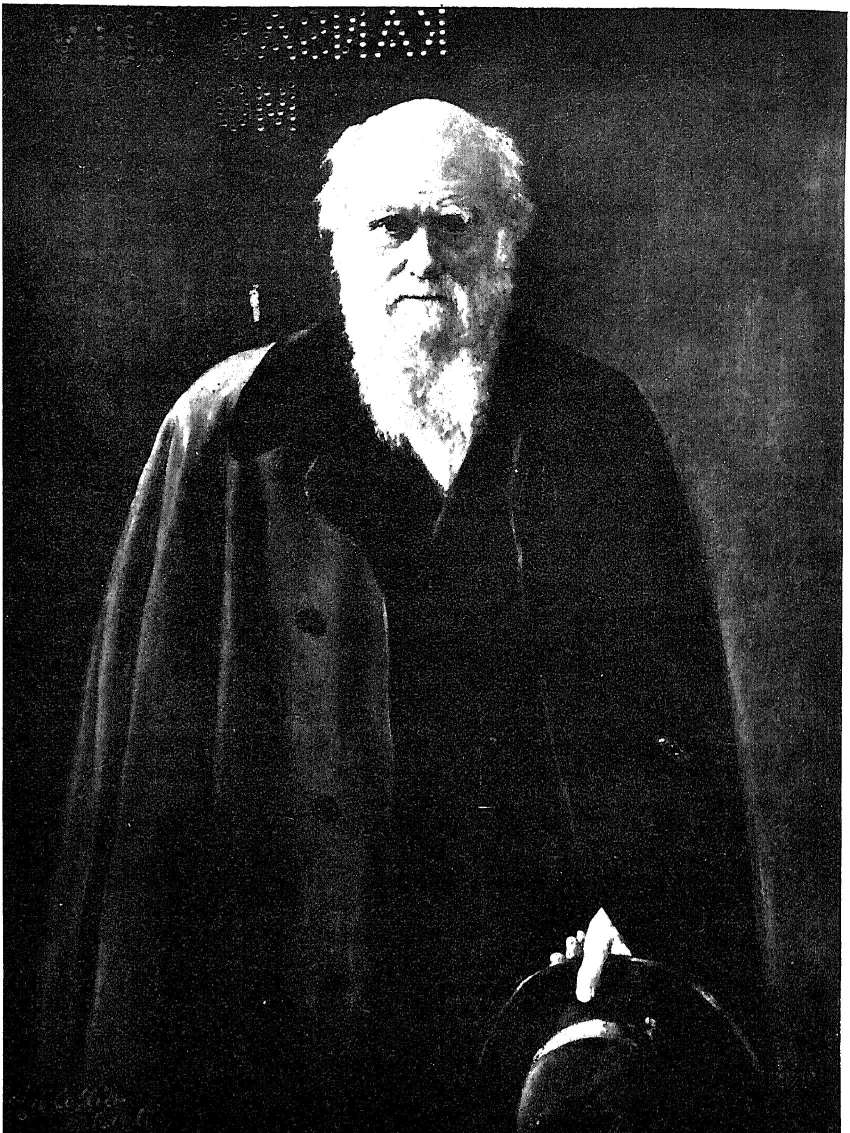

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CHARLES DARWIN

BIOLOGY

FOR EVERYMAN

by

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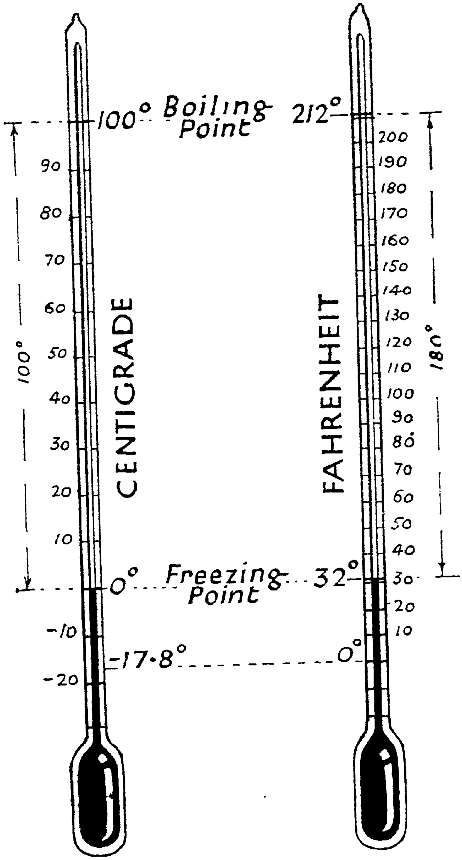

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BOOK II

ANIMAL LIFE IN GENERAL

CHAPTER I

THE DRAMA OF LIFE

What is life?—The drama of life—The quest for food—The struggle for existence—Modes of self-preservation—Shifts for a living—Animal weapons—Interrelations or linkages—The secret of sex—Parental care—Social animals.

What is Life?

This question of Life is a big one, not as yet fully answerable. Still, we must not simply say: We do not know what Life really is. For this confession would not be doing justice to the numerous investigations, continuing every year, that describe the chemical and physical processes that are always going on in the living body.

The student of engines can describe most of the operations of a railway locomotive in terms of what Francis Bacon called 'the secret motions of things.' He tells us about the invisible movements of molecules of carbon, hydrogen, and oxygen when the coal or oil is burned, about the invisible movements of molecules of water when the steam is formed to move the piston, and so on and so forth.

Similarly, the physiologist can tell us much that is very interesting about the chemical and physical processes that go on in our body. And while it is quite possible that this is not the way to discover the true inwardness of Life, it certainly brings many of the ongoings in the body into line with those that occur in non-living things like engines.

This is making progress towards a description of Life, though it must be confessed that the central secret seems to retreat as science advances.

Thus we know much about the contraction of muscles when we lift a piece of bread to our mouth, drawing one piece of skeleton nearer another, and yet we are not able to give more than a sketchy account of what happens when a muscle—a piece of flesh—in our arm becomes shorter and broader. We speak, and with some truth, of our muscles as the engines of the body, and then we remember that they consist of transparent threads of very watery living matter enclosed in very delicate films.

We touch a hot cinder on the fire-place and immediately draw back our hand, more quickly than we can utter a hasty word, but, although

we know, or can know, a great deal about the kind of **reflex action** that our movement illustrates—a nervous message to the spinal cord and back again, at the rate of about four hundred feet per second —we do not as yet understand what a nerve-thrill really is.

We know that the news travels along a transparent thread of living matter, that an electrical change occurs, that a little heat is given off and a corresponding amount of carbon dioxide, but we are not able to explain the nerve-message in terms of anything else.

We come down to **the irritability of living matter**—which is just a long way of spelling Life. This is what we meant by saying that the central secret seems to recede as science advances. Some day, perhaps, when all the minor mysteries have been cleared away, we shall get a glimpse of the major mystery of Life itself.

Life is a peculiar kind of activity that is exhibited by living creatures. And if you ask in what ways is it peculiar, part of the answer is that it is a kind of activity so *regulated* that it is able to continue for days or months or years, for it is self-preservative, and so *regulated* that it gets things done, for, even if it is not purposeful, it is always purpose-like, except in rare cases such as moths flying into the candle.

Yet when we say that Life is regulated activity, exhibited by living creatures, we are obviously miles away from any definition. For it is one of the laws of definition that it must not include, however well hidden, the thing that is being defined; and that is what we have done in the words 'activity,' 'regulated,' and 'living creatures.'

Still, there is some use in saying that Life is a peculiar kind of activity manifested by living creatures, for it shows that our question need not lose itself in metaphysics. We are not asking about 'a vital principle' or 'a vital force'; we are asking this question, to begin with, at any rate: What is peculiar in the activities of plants and animals and ourselves? What are the essential characteristics of living creatures?

The answer must apply to the hyssop on the wall as well as to the cedar of Lebanon, to the mite as well as to the mammoth, to the golden eagle as well as to the heather amid which it captures the unwary grouse. There is a long, long gamut from microbe to man, but all are alive; and it was a great step when Linnaeus, some two centuries ago, applied the word 'organisms' to all plants as well as to all animals and all mankind. Whatever is true of Life must be true of them all, except in cases of degeneracy and the like.

If we ask, *What is Man?* we are most likely to come towards a good answer if we take man at his best and not bushmen. So when we ask, *What is Life?* we are most likely to come towards a good answer if we begin with life at its best—as in the birds of the air, the beasts of the field, and the bees in their hive, as also in the lilies of a day and

the big trees of California, some of which have lived for three thousand years.

It is not at present possible to define Life, but there is a useful note in one of Herbert Spencer's descriptions—that 'Life is effective response to surroundings'; and to that I should like to add one of my own—that 'Life is the urge for more'—more food, more power, more room, more light, more self-expression, more life.

Let us now ask the chemist, the physicist, the biologist, and the psychologist—each in turn—to tell us very shortly what he thinks of Life.

The chemist tells us that all living creatures are built up of the same kind of stuff, which is called **protoplasm,** defined by Huxley as 'the physical basis of life.' Here is a chemical similarity that makes the whole world kin.

The chemist would tell us that he is greatly struck by the orderliness of the living laboratory, by the way in which processes of building up make good all the breaking down, and by the quickness and quietness of it all.

The expert on physics, who is chiefly concerned with energy (the power of doing work) and its changes, would tell us first that we must not suppose that living creatures *create* any energy. Like engines which change fuel into work, so organisms change the chemical energy of food into locomotion and work, sometimes into light, often into heat, and also into stores—especially in the plant world. But all living creatures are like engines in being *transformers* of one kind of energy into another. We say that a man is full of energy, but he will soon lose his 'go' if he tries to exist without his food.

On the other hand, the physicist tells us that he admires living creatures more than his own engines, because they get more energy in proportion out of their food than his engines get out of their fuel. A fish has more efficient engines than a battleship, and a fire-fly is a more economical light-producer than an arc-lamp.

The biologists are the experts on Life, and most of them would say that the characteristic activities of plants and animals seemed to them very different from those of the non-living world.

No doubt there are chemical and physical processes going on in every living body, but they are regulated and combined and harmonized after a fashion that seems unique. In the non-living world, say of suns and other stars, or in radio-active elements, all the clocks seem to be running down, but in living creatures they are always being wound up again—until the spring finally breaks in death. The organism is incessantly changing and yet it has the power of remaining much the same for many a year. Moreover, it can grow at the expense of food, often very different from itself, for the foal grows

by drinking milk or eating grass, and the grass gets its food from air and soil-water.

More than that, the living creature can reproduce or multiply, and from a pinhead-like germ-cell there develops a great edifice—plant or animal or man. There is nothing like this in the non-living world.

And, again, the world of life is full of novelties or new departures which form the raw materials of possible progress. Generation succeeds generation in a way that even the heavenly bodies do not show when a nebula gives rise to a system of stars.

Among the living generations there is struggling and sifting, and thus comes about evolution, which is still going on.

Give me Life at its best, says the psychologist, and I see it thrilled by Mind. Man shows Reason and Intelligence; many of the beasts of the field show intelligent behaviour; ants and bees are children of instinct; lower down still there are experiments of a simple sort, and everywhere among animals there is feeling.

Perhaps mind has never come to its own among plants, though we are often tempted to think that in their beauty we witness their dream-smiles. But even if mind never awakens in plants, it is a reality that counts in the life of many animals. Perhaps in some form it is at the very heart of life, enabling us to understand just a little the regulatedness, the unity, the power of profiting by experience and registering it, the purposelikeness, and the novel self-expressions that are so often to be found in living creatures.

No doubt we must not use big words like 'intelligence' for little creatures with just the beginning of a nervous system, but it may be that something of the nature of mind—perhaps 'sentience' would be a good word—is conterminous with life.

Just as there is no particular moment in an infant's or an embryo's life when we can say, 'Mind has awakened,' so in the world of life as a whole we cannot say, 'Lo, here,' or 'Lo, there.'

What begins as a slender rill of inner or subjective life becomes eventually a powerful stream.

Meanwhile, we welcome all that the chemist and the physicist can tell us about the ongoings in the living body; we remain none the less convinced that organisms are more than mechanisms; and we suggest as answer to our question, that Life is a dance of enchanted particles with Mind as the music.

The Drama of Life

What we said in the opening chapter of our Survey of the Animal World in regard to the characteristics of living organisms is, we think, both true and useful, but it is a little cold and bookish. It does not

suggest sufficiently **the drama of life**—its comedy and tragedy, its plots and struggles, its bustle and joyousness. Let us think again of what we can watch on the seashore, in the pond, in the wood, through and through the hedgerow, and so on. There is an extraordinary ambition about many living creatures; they are, as Goethe said, always attempting the next to the impossible; they are **insurgent.** We have suggested as a definition of living—' the urge for more.' Organisms are hard to satisfy; they struggle for more expression, more room, more food, more light, more love, more life. Some of them play, but most of them work hard; the struggle is often firmly fatal to ' the unlit lamp and the ungirt loin.' Life does not as a rule follow the line of least resistance; oftener it rows against the stream. Let the idea of Living Nature as a drama grow in our mind—a drama that has been played on the earth's changing stage for millions of years, a drama with a growing plot, a drama that is also a feast of beauty, a drama with a purpose—leading on to mankind.

THE QUEST FOR FOOD.—The activities of living creatures are mainly concerned with **hunger** and **love**—with (*a*) the quest for food, and (*b*) the production and care of offspring. We give prominence first to the quest for food, since all living creatures feed, obtaining supplies of matter and energy from outside themselves; and since it is in most cases the *surplus* food that leads to growth, and after growth to reproduction. In **green plants** the case is unique, for part of the energy of sunlight is used to build up carbon dioxide, water, and some salts into carbon-compounds, which then form the complex food that is directly comparable to that of ordinary animals.

The ways in which organisms solve the bread-and-butter problem are more numerous than one would at first sight suppose; and a dozen may be distinguished.

(1) An animal may devour a plant, as the sheep the grass. In other words, many animals are vegetarian or herbivorous; and it must be realized that the majority of animals are directly dependent on plants for food. Thus the world of life depends on the energy of the sunlight.

(2) Without devouring the plant or doing it any harm, the animal may eat what the plant has made. Thus the hive-bees feed on honey, and earthworms mainly depend on the decaying leaves that they drag into their burrows.

(3) A few animals are green with chlorophyll, and may thus feed like ordinary green plants. This mode of nutrition is called **holophytic.** But an animal that is green usually owes its green colour to the presence of minute partner-Algae in some of its cells, as in the freshwater sponge (*Spongilla*), the freshwater green hydra (*Hydra viridis*), and the little shore-worm *Convoluta*. This mode of nutrition

is called **symbiosis** (q.v.). Some green sea-anemones and corals have thousands of these partner-Algae or symbionts in the cells of their body. On the other hand, there are a few animals which have chlorophyll of their own, and are thus able to live holophytically though they have no partners. As an example may be mentioned the green bell animalcule (*Vorticella viridis*). Green animals that have chlorophyll of their own, or in their symbiotic partners, are to be distinguished from those in which the green colour has nothing to do with chlorophyll, e.g. green beetles, green birds, and the quaint sea-worm called *Bonellia*. In the green beetles and birds the green colour is due, not to a green pigment of any kind, but to the physical structure of the surface and usually, at the same time, to some pigment that is *not* green. In Bonellia there is a green pigment (*bonellein*), but it seems to be chemically quite different from chlorophyll.

(4) An animal may feed on another living animal—the familiar carnivorous habit with all its variety. Through the whole world of life we see a sequence of **reincarnations**, along nutritive chains which are sometimes long and sometimes short. The gull eats the fish, the fish eats the crustacean, the crustacean the worm, the worm the animalcule, and so forth. In the long run the chain must have green plants as its first link; *thus all flesh is grass*.

When a hungry man eats a pound of cod-fish, he is eating what it took the cod ten pounds of whelk to build up. But each pound of whelk required for its making ten pounds of sea-worms, and each pound of sea-worms required in turn for *its* making ten pounds of sea-dust. Thus the hungry man's meal consists of a thousand pounds of transmogrified sea-dust, meaning by that, minute organisms and organic particles.

The mackerel is a dainty feeder, depending mainly on minute Open-Sea crustaceans called Copepods. These in turn depend on microscopic marine plants called Diatoms and very small infusorians called Peridinids. And when we eat the mackerel there is the highest incarnation of all.

When a dead animal is rotted by bacteria, the results of the decomposition pass into the air, the soil, and the water; they may be absorbed by plants and built up again into complex products; and these may be part of the food of animals, thus completing the circle.

(5) An animal may feed on dead flesh, as in the case of a carrion-beetle; and there are on land and in the sea numerous **scavenger animals** that play an important part in keeping places clean, and, more generally, in the **circulation of matter.**

(6) An animal may feed on decomposing organic matter that has been prepared for it by bacteria. The organic matter may be a rotten organism such as a decayed plant, or a rotten part of an

organism such as a fallen leaf. Many threadworms or *Nematoda* feed on dead organisms which have been previously rotted. Many fungi also live on rottenness, and this mode of nutrition is called **saprophytic.** It is difficult, of course, to draw hard-and-fast lines; thus the salmon-disease fungus (q.v.), battening on the living fish, depends on material which has been previously prepared by bacteria.

(7) An animal may feed on organic débris, what we may call crumbs, broken off from living organisms. This is important in places like the seashore, where many animals utilize the minute débris particles washed about by the tide. Similarly the bud-scales and the like, which fall from trees, are crumbs very welcome to many humble animals on land. Perhaps there should be a special section for animals and plants (**coprophagous**) that feed solely on dung.

(8) It is biologically convenient, though not perhaps logically justifiable, to make a special group for those animals which feed on microscopic plants and animals, such as those **minute-plankton** organisms which drift in the open waters of sea and lake, or the **minute-nekton** organisms which swim about in the same environment. Some of the single-celled animals (*Protozoa*) that are slow in their movements, such as the radiolarians, illustrate the minute-plankton of the sea, while the common luminescent infusorian called *Noctiluca,* as large as a pin's head, may illustrate the minute-nekton. For our present purpose these are to be distinguished from members of the **large-plankton,** like the gently swimming or merely drifting jelly-fish, and from members of the **large-nekton,** such as herring. Our point is that many animals feed at a microscopic level.

(9) An animal may thrive by reason of its **partnership** with another animal, whether there be (*a*) an internal partnership (**symbiosis**) like that of the infusorians in the food-canal of all wood-eating termites, or (*b*) an external partnership (**commensalism**) as in the familiar case of certain sea-anemones and hermit-crabs, where the meals of the former depend largely on those of the latter. The commonest kind of partnership, already referred to, is between symbiotic Algae and some animal, such as a green *Hydra.*

(10) An animal may be an **external parasite** on the surface of its host's skin, where it cleans up the surface, as is well illustrated by lice and some mites. The number of gradations makes strict pigeon-holing impossible, for some external parasites suck blood or body-fluids through the skin, like the leeches on some fishes, and others insert part of their body into their hosts, as ticks do with their proboscis.

(11) An animal may be an **internal parasite,** living in the interior of its host. It may feed, as tapeworms do, on the digested food in the food-canal; or it may suck the blood through the walls of the intestine,

as the hookworm does. Most parasites feed very passively, and most of them show marks of degeneration.

(12) When an animal is **predatory from within**, like the ichneumon-grubs that are hatched inside a caterpillar and devour its tissues, it should, we think, be removed from among the parasites.

In each of these twelve groups there is variety and subtlety, and this is interesting in giving us some picture of the intensity of **the struggle for existence.** For it is this struggle or endeavour that is behind the promptness with which animals seek out profitable niches of opportunity.

THE STRUGGLE FOR EXISTENCE.—This phrase that Darwin coined is on every one's lips, yet it is not always clearly understood. As Darwin said, it is to be used in a 'large and metaphorical sense,' including endeavours to secure the welfare of the offspring as well as life-and-death competition at the margin of subsistence. It rises from a keen competition that draws blood to a subtle endeavour after well-being. It may be defined as including all the activities of living creatures when they have to face difficulties and limitations in their environment.

The struggle may be (*a*) between organisms of the same kind, e.g. rat against rat; or (*b*) between organisms of quite different kinds, e.g. carnivore against herbivore; or (*c*) between organisms and their changeful surroundings, as when the deer struggles against the winter storms or the plant against drought. The environment makes a thrust and the organism seeks to parry. The struggle may be for **food**, for **foothold**, for **shelter**, for **mates**, for **satisfaction of appetite,** and so on. It is manifold in its nature and almost ceaseless in its occurrence.

MODES OF SELF-PRESERVATION.—Man thinks out ways and means of countering dangers and difficulties, but it is only the higher animals, if even these, that we can venture to credit with ever having a conscious policy. The higher animals are no fools, and they may become aware of ways that spell danger and of others that ensure safety, but we must not think of them as *deliberating* over the most effective ways of behaving. They have characteristic activities, which we may think of as hereditary self-expressions, and in the struggle for existence these may become racial ways of behaving which are justified by their success in meeting risks and securing safety, but this is very different from a deliberate pondering over self-preservation. Also different are those responses, sometimes intelligent and sometimes at a lower level, which prove successful and are repeated so often in the individual lifetime that they become **habituations.** They come to be very ready whenever the trigger of danger or the like is pulled, or sometimes when what is pulled is not exactly the trigger of danger

but some sight or sound that has come to be associated with the danger. Answers-back of this last type are called **conditioned reflexes,** as when the young bird squats at a sound which has come to be inextricably associated with real danger.

If we are careful not to think of self-preservation among animals as if it were usually deliberate, we may give the following as illustrations of different ways in which it may be secured:

(1) Strong armour, such as the bony outside skeleton of an armadillo, or the calcareous shell of a sea-urchin.

(2) Very effective weapons, such as the canine teeth of a tiger or the talons of an eagle.

(3) Ways of securing disappearance in face of danger, e.g. by very rapid movements into relative safety, by taking to aërial flight, by burrowing, by climbing, by hiding, by lying low and motionless, by having some cloak of invisibility such as colour-change.

(4) By seeking out a new habitat, for the time at least, as when migrant birds escape the risks of winter.

(5) By being unpalatable or poisonous, as some caterpillars and amphibians are to birds.

SHIFTS FOR A LIVING.—Along with self-preserving qualities and ways may be ranked more complicated arrangements and doings which attain the same end. They correspond to what are often called 'shifts for a living' in mankind, but in regard to most of them we do not know enough to be able to estimate the degree of deliberateness, if any, that they may possess. There is a little spider-crab (a species of *Stenorhynchus*) which finds shelter under a sea-anemone (*Anthea cereus*), hiding between it and the rock to which it is as usual fixed. When the crab returns from hunting with booty in its claws, it retreats below the sea-anemone and begins its meal. But it has not gone far before the sea-anemone lowers one of its long tentacles and steals the booty. After it has utilized the food it may allow the residue to sink down to the waiting crab. The sea-anemone has a network of scattered nerve-cells in and below its skin, but it has no nerve-centres or ganglia, and we cannot use any big psychological word, like 'intelligence' or 'inference,' in describing its behaviour. And yet this behaviour has an interesting spice of deliberateness about it, and we may call it objectively 'a shift for a living,' without begging any question in regard to its mental or subjective aspect.

(*a*) **Masking.** A shore-crab, e.g. *Hyas araneus*, may be sometimes seen biting off a piece of seaweed, chewing one end a little in its jaws, and then rubbing it on the back of its shell till it catches on some of the bristles. The fixed seaweed may actually grow, and, along with others similarly treated, it may cloak or mask the crab so that the latter is helped by the disguise to approach its victim or escape from its enemy.

Sometimes the crab does the same with pieces of sponge or zoöphyte, and the active planting out of these is not to be confused with the passive way in which a crab may be partly hidden by acorn-shells, worm-tubes, and moss-animals (*Bryozoa*) which anchor there as larvae, much in the same way as they might anchor on a stone.

(*b*) **Self-mutilation or Autotomy.** A not uncommon occurrence on the seashore is the dislodgment of a stone by the tide, with the result that a starfish is pinned down by one of its arms. If the starfish cannot free itself, it may save the situation by surrendering the fixed arm. A strong contraction of muscles at the base of the arm results in a breakage, and the starfish is free. This is a **reflex action,** the muscles being stimulated to contraction by commands from motor nerve-cells, which in turn have been provoked to activity by an impulse from sensory nerve-cells, thrilled by stimuli from without. There is no warrant for supposing any intelligent awareness on the starfish's part, especially since it is devoid of any concentration of nerve-cells into **ganglia.** Autotomy is not to be mixed up with the much more complex self-mutilation we occasionally see when a trapped rat or a stoat gnaws off a leg. This is grimly deliberate.

True autotomy may be illustrated by a crab surrendering a limb, a lizard its tail, a worm a considerable part of its body, an insect or spider its leg, and so on. It is a very common device, and as it is usually followed by a **regeneration** or regrowth of what has been surrendered, it is of notable advantage in the struggle for existence.

(*c*) **Mimicry.** This word, like ' masking ' and ' autotomy,' is a little apt to suggest a deliberate endeavour, such as we ourselves might make for safety's sake by trying to look like someone else who was by reason of his appearance safe in the face of menacing enemies. But in the case of animals there is no warrant for supposing that the resemblance is other than the outcome of **inborn variations** and inherent *laws of growth,* and of **sifting** or **selection** in the course of many generations. It is in no sense a conscious mimicking; though a conviction of this should not lead us to doubt that animals may play their hereditary cards with useful results. This may include consorting with others like themselves who are in some way relatively safe against enemies, e.g. by being unpalatable.

In ordinary (Batesian) mimicry certain animals (the so-called *mimickers*) without special protection against particular enemies have secured relative safety, in this respect, by having an extraordinary resemblance in colour, pattern, and the like, to certain other not nearly related types (the so-called *mimicked*) which have life-saving qualities such as unpalatability. Thus a palatable butterfly may usefully consort with a similar, though not closely related, species

that is unpalatable. Or a fly may be like a stinging bee, or a spider like an ant, or a harmless snake like a venomous one.

In another kind of mimicry, called Müllerian, the 'mimicker' is unpalatable as well as the 'model.' The theory in this case is that the mimicry serves as a mutual assurance, the members of the company or ring all being safer by having the same livery, which has somehow come to mean to their enemies, 'Leave me alone.' The two kinds of mimicry are called after their discoverers, Henry Bates and Fritz Müller.

There are other 'shifts for a living,' but we are only attempting an illustrative survey. Perhaps we should include 'warning colours'; striking 'terrifying attitudes'; 'feigning death'; expelling a cloud

Courtesy of the Natural History Museum

FIG. 303. NARWHAL (*Monodon monoceros*)

of ink into the water, as cuttlefishes do; producing a warning sound, like the rattle of the rattlesnake; rapidly changing colour as in flat-fishes, Aesop prawns, and chamaeleons; and there are many others. They should be seen against the background of the **struggle for existence** in its manifold forms, for, given a crop of novelties or variations, it is selection in the struggle for existence that has engendered the life-saving or life-promoting 'shifts,' and continues to give them encouragement.

ANIMAL WEAPONS

Perhaps the most formidable of all animal weapons is the spear of the Arctic narwhal, which might well be called the 'unicorn whale.' Indeed, its technical name, *Monodon monoceros*, is unusually eloquent. The spear or 'horn' is the longest tooth in the world, for it may be eight feet in length. This puzzles us a little, for the body of the whale

itself is only about fifteen feet long. The spear is a magnificent piece of spirally-twisted ivory. It is a left incisor (occasionally with a smaller companion on the right), and it is confined to the male. The female narwhal may have a quite rudimentary representative of one or of both. Thus we see that the great spear is a sex-linked character, belonging to the same series as antlers, which never occur in females except in the reindeer. The development of the spear is in all probability provoked by masculine hormones, and, as happens in other cases, the provocation may go too far. It is difficult to believe that a fifteen-foot animal can need an eight-foot tooth. As a matter of fact, the use of the spear is uncertain. Two males sometimes cross spears; the weapon may be of service against some large enemy; it may be for breaking a breathing-hole in the thick ice; and Captain Scoresby thought it was used to impale big skate.

The secretary-bird of South Africa, a long-legged terrestrial hawk, has three weapons—feet, wings, and beak. When the snake strikes there is a pretty play of agility. The bird skips to one side, jumps backwards, or springs into the air. Or it may receive the thrust on the stiff feathers of the outer half of the wings, with which it then delivers a slashing blow. This is followed by a very rapid forward kick. If this is a 'knock-out,' the bill comes into operation, but the swallowing process may be aided by taking the snake up in the air to a great height and letting it fall on the hard ground. This dislocates all the vertebrae.

In this study we are keeping away from venomous animals, otherwise the fangs of snakes would furnish the best illustration of reptilian weapons, but there are many other instances. A crocodile may kill a man with a stroke of its very muscular tail, and among the worst of bites must be ranked those of some of the turtles, like the snapping turtle, common in North American pools and streams, and the alligator turtle of the Mississippi, which can bite off a piece of plank more than an inch thick. It is interesting that such formidable bites should be given by animals without teeth, but the horny covering of the jaws is strong and sharp-edged, and the muscular development is unsurpassed.

There are no weapons among amphibians, but they abound among fishes. The swordfish (*Xiphias gladius*) is a bony fish, toothless and scaleless, not distantly related to mackerel. It occurs in almost all the seas, and does great havoc among other fishes by slashing with its sword. This is a prolongation of the upper jaw, and may be over two feet long on a fish of eight feet. There is no doubt as to the way in which Xiphias uses its sword; it slashes to right and left among mackerel and herring and other fishes that swim in shoals. After much slaughter it proceeds to eat. It is also known to attack squids

and whales, and the quickness of its movements increases the cutting power of its blade.

On a different line altogether is the sawfish (*Pristis*), a cartilaginous fish related to the skates. It is common in warm seas, a quick swimmer, and very formidable. It may be ten to twenty feet long. The saw (see Fig. 174) is a flat prolongation of the snout, sometimes six feet in length and a foot broad at the base. On each side it bears very strong teeth, like those of a reaping-machine, projecting straight out from gristly sockets. There may be a score or more of these teeth on each side, and the saw gives a ghastly wound. It can be used to rip up a small whale or to tear off a huge slice of flesh. The sword-fish is generally regarded as a swashbuckler of the sea, and we do not know who could stand up to it. A point of interest is that the true teeth are small and blunt; so the use of the saw is said to be to cut off pieces of flesh suitable for swallowing. On the other hand, some naturalists are convinced that the 'weapon' is used for grubbing in the deposits on the floor of the sea, and turning up small edible fry of various sorts. This is rather a tame sort of swashbuckling, but it may be that both stories are true. In a family of sharks (*Pristiophoridae*) a saw is also developed by a great prolongation of the front of the skull—much the same as in the sawfish, but differing in detail. There can be little doubt that this implies the quite independent evolution of two similar weapons, one on the skate line and the other on the shark line.

In the sting-ray or *Trygon* (see Fig. 183) there is a group of toothed spines at the base of the tail, representing the transformed remains of the dorsal fin. The oldest spine is the one that is used, and as its exquisite serrations are worn blunt by striking against enemies, it drops off and the next in order takes its place. The spine is sometimes used as a spear-head.

The subtlest weapons among fishes are the electric batteries of the *Torpedo* (see Fig. 175) and the electric eel and other similarly endowed forms. They are able to give a shock that kills small booty and sends large enemies off at a tangent. But this, like poisoning, is a big subject in itself. Let us keep to mechanical weapons.

Weapon-bearing backboneless animals come crowding on the stage, even when we keep back those that inject venom like bees and wasps, spiders and scorpions. There are the cuttlefishes with grappling, sucker-bearing arms, jaws like a parrot's beak, and a rasping, file-like ribbon in the mouth. All the snails and slugs of land and sea have likewise this rasping ribbon, with which they can bore through a thick shell, helped in some cases at least by a little acid from their mouth. Perhaps the rasper or **radula** should be called an instrument or tool rather than a weapon, but it is very difficult to draw the line. Thus the great

claws or forceps of crabs and lobsters are of service in seizing the food and also in locomotion, but they are greatly used for fighting. It is Nature's way to put things to new uses. Thus one of the forceps of the male fiddler-crab, almost as big as the rest of the body and brightly coloured, seems to be chiefly of use as a signal that excites the attention and interest of the female; and part of the use of one of the forceps in a hermit-crab is to serve as a door for the borrowed whelk shell.

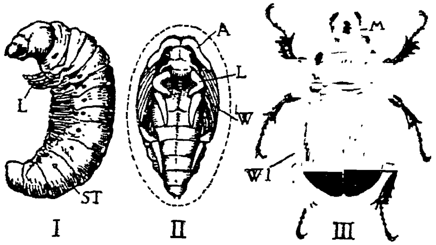

FIG. 304. STAGES IN LIFE-HISTORY OF STAG-BEETLE

I. Larva: L, legs; ST, stigma. II. Pupa: A, antenna; L, leg; W, wing. III. Adult: M, mandible; W1, wing-case or elytron.

Many insects, like mosquitoes, have a set of surgical instruments in the service of the mouth, and these are often on the verge of being weapons; it is also rather difficult to say whether the borer used by an ichneumon-fly in piercing the skin of a caterpillar for egg-laying purposes is a weapon or a tool. It is remarkable that the structures that look most like weapons are sometimes those that least deserve the name. In some of the stag-beetles (*Lucanidae*) the mandibles of the male are huge and strongly toothed. They may be an inch long—nearly as long, indeed, as the rest of the body. What better examples of weapons could we wish? And yet our knowledge of the use of these enormous jaws is very unsatisfactory. Some authoritative naturalists have described certain male stag-beetles fighting furiously to the death; but Dr. David Sharp, the very careful author of the two volumes of the *Cambridge Natural History* that deal with insects, wrote: 'So far as we have been able to discover, these structures are put to very little use, and in many cases are not capable of being of service even as weapons of offence.' We suspect that many of these structures are, like the narwhal's horn, expressions of masculinity run riot.

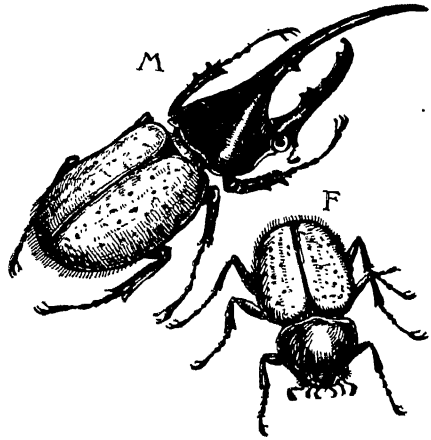

FIG. 305. HERCULES-BEETLE; MALE (M) AND FEMALE (F)

This is probably true of the huge horns on the head and prothorax of some Hercules-beetles (*Dynastes*). Neither horn is movable, but they come together like pincers when the head is thrown back against the prothorax. In one case the prothorax horn is three inches long.

We have not given more than a few samples of the weapons in the animal kingdom, and there are many that we have not even named—horns and hoofs, spurs and talons, and all the venomous weapons. But enough has been said to show that people do not use a figure of speech when they talk of the battle of life.

Interrelations or Linkages

Ecology is a new word for the old study of Natural History. It is more precise, discriminating, and orderly than much of the old-fashioned Natural History, but it expresses the same attempt to understand living creatures in relation to their surroundings, animate as well as inanimate. It is the study of life as it is lived in Nature, where the circle of each individual's interests is intersected by many other circles—such as kindred, members of the same species, competitors, deadly enemies, parasites, symbionts, and so forth. Ecology is concerned with interrelations or linkages, with ways of living, with adjustments to space and time. Thus it includes the study of numbers and dispersal, of migration and other seasonal reactions.

Ordinary physiology is concerned with the internal economy of the individual body, but ecology, which Semper called 'the higher physiology,' has to do with external relations, rising to the political economy of the animal community. The transition from individual physiology to ecology is in the study of reproduction, for that leads from organism to organisms. To Pearse and to Elton we owe two good English-written books on 'Animal Ecology,' and there are half a dozen or so on 'Plant Ecology.'

One of the main tasks of ecology is to decipher the patterns in the web of life. A central idea is that every creature's life-circle intersects or is intersected by other circles. Thus, it is an old story now that lichens are dual plants made by an alga and a fungus living in partnership, and that all radiolarians enclose unicellular algae with which they live in mutually beneficial symbiosis; but how many new instances have been discovered in recent years! We recall the microbes that make root-tubercles in leguminous plants, like clovers and vetches, and somehow enable their hosts to tap the endless supplies of atmospheric nitrogen; the partner-fungus that interpenetrates the heather from root to shoot, from leaf to flower, from seed to seedling, and enables the plant to thrive where nothing else will grow; the mycorhiza that enswathes the roots of many trees and is indispensable to the health of the aristocratic orchids; the yeast

plants that produce fermentation in the food-canal of cockroaches, and are in some way indispensable to the wood-eating larvae of many beetles, like the death-watches and various longicorns. Perhaps the most striking instance is that of the very beautiful infusorians, whose sole habitat is the intestine of wood-eating termites, where they do something to the dry-as-dust food that is absolutely indispensable. By raising the temperature it is possible to kill off the infusorians without harming the termites, and then it is found that the insects can make nothing of their food. They soon die unless they are rescued in time by introducing a fresh supply of infusorians. Thus plant lives within plant, as in lichens and Leguminosae; plant lives within animal, as in green sponge, green hydra, green convoluta-worm, and the yeast-containing insects; and animal within animal, as the specialized infusorians do inside termites. There seems to be no end to these symbiotic linkages, and some are very surprising. Thus certain luminous cuttlefishes shine with a borrowed splendour, for the light seems to be produced by nests of harmless luminous bacteria, such as we see on the glistening surface of the haddocks hung up to dry. In most cases, however, animal luminescence is a by-play of the normal metabolism of the animal itself—a rapid fermenting of a luciferin by a luciferase. This is probably always true when there is a special light-producing organ. (For further details of many of these examples, consult the INDEX.)

The disclosures of the ecologists warn us against taking simple views of living things. Animate Nature has been in progress for so long that it is hardly surprising to find it in many cases very subtle. Some beetles that bore in growing wood have no symbionts in their food-canal, but on the walls of their tunnels they grow a mould that yields what is called 'ambrosia.' The fungus collects, concentrates, and prepares the sap, and in some cases it has been proved that the beetles do not eat the wood as such, but depend entirely on the ambrosia. The fungus does not seem to form spores or other elements specialized for propagation, so it is probable that the beetles infect a new tree with surplus vegetative ambrosia-cells which have passed out undigested from the food-canal.

Everything becomes more complex as our knowledge deepens. We thought we knew a little about hive-bees, but how the intricacy has grown of recent years! There is the quaint, excited dance of the worker-bee which comes to the comb heavy with her new-found nectar —a dance that often gives her sisters their clue to the treasure-trove. How the story would have pleased Darwin, who said, with a twinkle in his eyes, that bees were good botanists, and pleased Aristotle too, who spoke of the way in which bees refrained from mixing their drinks!

Animal ecology is wider by far than our illustrations have indicated; it has to do with associations and communities, families and pairs thrust and parry with environment and with the seasons, trading with time and trafficking with circumstance, migrations and trekkings, outgoings and incomings. Of the last let us take a final illustration, though it brings us back to bees again. Wolf has shown that the homing depends partly on visible landmarks that have been learned, partly on the odour of the hive, and partly on 'a sense of direction' which has its seat in the antennae. By means of these organs the bee is able to record movements until it begins to 'lose count.' When bees are fed for the nonce at a point 150 yards due north of the hive, a captured one released from its box flies at once southwards. But if the captive is carried in the box 150 yards due east of the hive and then released, it flies again due south. When it has covered 150 yards (judging the distance to ten yards) it hesitates, apparently realizing that it is quite wrong, and then proceeds to circle around until it finds the hive by sight and scent. This is not nearly all, but it is enough. It shows us what uncanny capacities are being discovered by animal ecology.

As an instance of the frequent subtlety of interrelations, take Roubaud's account of what takes place in the domestic economy of some African wasps. The mothers bring ready-chewed flesh to their grubs, whose jaw apparatus is very poorly developed. But as the mother supplies the meal the young larva exudes from its mouth a drop of salivary juice, and this seems to be a kind of elixir to the mother wasp. A curious alimentary linkage is established, which Roubaud calls a 'coeno-trophobiosis.' By any other name it would sound as strange. But only the young larvae secrete the elixir, and this fact tends towards the establishment of a *ménage* in which throughout the season there are continual relays of children. Just as tailor-ants use their larvae as living gum-bottles for binding the leaves together, so certain wasp-mothers obtain from their offspring little luxuries which, for animal as well as man, often mean more than necessaries. If such linkages were few, one might dismiss them as curiosities of Natural History, but they are numerous and many are discovered every year.

THE INTRICACY OF LIFE.—One of the great makers of history once said that a square yard of meadow is like a tropical jungle when you look into it carefully enough; and we knew a naturalist who used to show us a score or so of plants and animals within reach of his hand when he sat down to rest almost anywhere in the country.

Living Nature is indeed like a fine picture, you see more and more in it the longer and closer you look. There may be twenty kinds of animals clustering on a stone brought up by the dredge from the floor

of the sea. We get an impression of intricacy, partly because Life is so abundant, partly because it has been a going concern for many millions of years, and partly because it is in the very nature of Life to form linkages.

We examined, not long ago, the egg-cell of a common animal. It was much smaller than a pin's head, but under the microscope it looked like a little world; and in it we knew there lay the possibility of developing into a large and complicated animal. It was a microscopic sphere of living matter, and it showed a complicated foam-like or net-like structure. In the middle of the living matter was a special kernel, with curved rodlets inside it which are believed to carry part of the inheritance of the creature.

Inside this kernel was a second kernel, seen as clearly as a cricket-ball; and inside the second kernel were smaller bodies still. We do not say that these smaller bodies were important—perhaps they were only bubbles; but there were, within these minute limits of size, three spheres, one within the other. And this sort of thing is to be seen everywhere—world within world. This is just a little part of the great truth the poet Blake had hold of when he spoke of seeing

A world in a grain of sand,
And a heaven in a wild flower.

In Mr. Beebe's story of jungle life there is a study of a yard of jungle—a yard round about a wild cinnamon tree. With high-power glasses the naturalist studied the life of the tree for a week—the birds and insects, the creepers and the perched plants. He identified seventy-six kinds of birds visiting that one tree, and, when he had to say good-bye to the cinnamon tree, he took an empty war-bag and swept into it four square feet of leaves, sticks, moss, earth, and other fragments.

A week later he studied his bag on board ship. When he had studied the life of the great tree he said he was in the land of Brobdingnag; on the ship with his bag he was verily a Gulliver in Lilliput. The bag teemed with mystery as deep and inviting as any in the jungle itself. He secured over five hundred little creatures, and was sure that he had left as many undetected. There were mites and spiders, tiny beetles, miniature worms, and the smallest snails in the world—a thousand creatures in four square feet of rubbish, so that a square mile of jungle floor, with its thin layer of fallen leaves, sheltered more than six thousand million creatures.

What a glimpse of worlds within worlds! Perhaps we should remember, too, that the smallness of most of the creatures does not make the puzzle of Life's intricate abundance any less.

The riddle of the jungle was in the bag of fragments. As Whitman

says, the ant, the grain of sand, and the egg of the wren are as perfect as the journey-work of the stars. The grain of mustard-seed is small, but it grows into a big plant; and, while tiny creatures seem Lilliputians to us, they are not small to one another, for, as Mr. de la Mare writes:

How large unto the tiny fly
Must little things appear!
A rosebud like a feather bed,
Its prickle like a spear;
A dewdrop like a looking-glass,
A hair like golden wire;
The smallest grain of mustard-seed
As fierce as coals of fire.

And if you ask, 'But is there no light to be thrown on the riddle of this overflowing abundance of life and this intricate complexity of worlds within worlds?' perhaps the wisest thing one can say is what Tennyson said when he looked into the stream and saw all the bustle in a little pool: 'What an imagination God has!'

LINKAGES AMONG ORGANISMS.—All through the world of life we find living creatures linked together in interdependence of some sort. One may eat another or cradle another; an insect may pollinate a flower, but the sundew catches the fly; a bird destroys the buds, but the missel-thrush plants the mistletoe; the microbe kills a king, but the bee makes honey for the queen in her parlour; a fungus rots a tree, but another makes the heather a success on the moorland; and so one might go on, page after page. A linkage is not a curiosity of Natural History, it is an instance of a tendency which interpenetrates the world.

Why should there be so many linkages? Some of them, like the dependence of animals on green plants for food, are so fundamental, that we can only say: Why, that is the plan that has made the world of life possible. In other less general cases we may say: This was a very crowded corner; there was not standing room for all; can we wonder that some got up on their neighbours' shoulders? Again, it may be that living creatures, full of inborn insurgence, engaged in some very difficult adventure, and were half-forced, half-inspired to form some alliance, or unconsciously to clutch at a neighbour's arm. At any rate this is a question to think over: Why are linkages so common among living creatures?

Illustrations. Let us gather together some of the interrelations we have already discussed in earlier sections, and add some new ones:

(1) Animals depend on green plants for food, either directly or indirectly.

(2) Nutritive chains often link many creatures together, e.g. gull, mackerel, crustacean, infusorian.

(3) Bacteria decompose dead organisms, and the results of the decomposition may be absorbed by plants.

(4) Many flowers are pollinated by insect-visitors, such as bees and butterflies.

(5) There are not a few carnivorous plants, like sundew.

(6) One animal may serve as the necessary cradle for the young stages of another; thus the freshwater mussels are needed in the life-history of bitterlings, and freshwater snails in the life-history of the liver-fluke.

(7) Many an organism is a parasite in or on another, e.g. tapeworm in man, tick on tortoise, dodder on nettle.

(8) There are many useful external 'partnerships' (commensalism), e.g. sea-anemones borne by hermit-crab.

(9) There are many useful internal 'partnerships' (symbiosis), e.g.:

- (*a*) between plant and animal, like the unicellular algae in the worm *Convoluta*;
- (*b*) between plant and plant, e.g. the fungus interpenetrating the heather;
- (*c*) between animal and animal, e.g. infusorians in the food-canal of termites, indispensable in the utilization of the sawdust-like food.

(10) An animal often serves to disseminate another: thus a bird may scatter swallowed seeds which it has not digested; or prickly fruits may adhere to the skin of a furred animal, e.g. hare, and eventually fall off.

(11) Some insects, e.g. among ants and termites, may shelter other insects, e.g. small beetles and flies, and take care of them, receiving some luxury in return.

(12) As we have noticed, not a few animals may show some degree of social life, from simple gregariousness, as in the rabbit warren, to intricate communal life, as among ants and bees.

LINKAGES AND STRUGGLE.—The multitude of interrelations should be envisaged in the light of the struggle for existence, and in two ways. In the first place, it seems reasonable to suppose that the intensity of the struggle has sometimes led organisms to hang on to their neighbours, taking advantage of every niche of opportunity. In the second place, the continual sifting and winnowing that goes on in Wild Nature is not in the main a chance thinning, though that may occur; it necessarily works in reference to the already woven **web of life.** This makes the sifting very subtle; it determines, so to speak, if we may recall the vivid Old Testament story, the survival

of animals that can say ' Shibboleth,' and the elimination of those that can only say ' Sibboleth.'

LINNETS AND DANDELIONS.—What is the connection between linnets and dandelions? The question has been recently asked and answered by Dr. Joseph Grinnell, one of the Professors of Zoology in the University of California. The dandelion is a very beautiful and interesting plant, but it is a weed on the lawn; and though it fills the grass with stars, its presence is regarded by the householder with great disfavour. To Professor Grinnell's discerning eye, however, it became evident that it is an ill wind that brings nobody good. The wind that blew in the dandelion-down also brought the Californian linnets or house-finches, which are among the most cheerful songsters of that part of the world. And how does the wind bring the linnets? Simply because these birds are particularly fond of dandelion-down. Early in the spring morning, the male linnets come out of their shelter among the untrimmed vines on some of the older walls, and pour forth their song from the wood-shingles of the roofs. About seven in the morning, as the sunshine first sweeps the weedy lawn, the linnets descend and seek out the heads of the dandelions. Each female is closely attended by a jealous male; each pair keeps to itself in a different part of the lawn; all are after the down before it sets sail. We quote Grinnell's summary, for it illustrates one of the central facts of Biology, that nothing lives or dies to itself: ' Oldish houses with untrimmed vines about them; rather informal, therefore carefree, householders; lawns with dandelions in them; then linnets; and therefore, mornings and evenings, the neighbourhood pervaded by the most heartening of Californian bird-songs.' We are not, of course, recommending the cultivation of weeds—we must not be woodenly serious about such matters—we are simply giving a picturesque instance of interrelations, and reminding ourselves and our readers that if every rose has its thorn, even weeds may make for music.

Sometimes there is a triple alliance. Thus gall-midges that attack flowers of mulleins, scrophularias, and capers provoke galls inside which an ambrosia fungus (q.v.) flourishes. There are beetles in the hollow petioles of the *Tachygalia* trees that have established an alimentary partnership with minute mealy-bugs that share their shelter and yield honey-dew in response to urgent massage. Bug, beetle, tree—a triple alliance.

WHEELS WITHIN WHEELS.—A tree may be a circle which many other life-circles intersect, and a good example has been reported by Drs. A. Barbey and Ch. Ferrière from Switzerland. As every one knows, the Scots pine (*Pinus sylvestris*) is attacked by many insects, especially beetles. Very frequent are the galleries excavated by the hylesine-beetle (*Myelophilus piniperda*), both as a grub and when it

becomes a perfect insect. Inside the vacated galleries of this pine-beetle the Swiss naturalists found three different kinds of *Hymenoptera*. There were larvae of a small burrowing wasp or sphegid (*Passaloecus brevicornis*), which had been supplied by the mother insect with a living larder of paralysed aphids. But there were also the rough cocoons of a ruby-wasp or chrysid (*Ellampus auratus*), and in the same gallery there were the silken cocoons of an ichneumon-fly (*Lochetica pimplaria*). The larval stages of both of these were hostile to the wasp-grubs. Then there were marks on the tree showing that a woodpecker had been successfully investigating the Hymenoptera. Thus we have complex linkages: (1) the pine-tree, (2) the pine-beetle, (3) the young wasps, (4) their aphid-food, (5) the chrysids, (6) the ichneumon-flies, and (7) the woodpecker.

MORE WHEELS WITHIN WHEELS.—Earwigs are not usually very troublesome in this country, but they sometimes become a plague, and that has been the case recently in New Zealand. In this connection it is very interesting to hear that already the entomologists at Rothamsted have been rearing huge numbers of two minute insect-enemies of the earwig, and are shipping these to the Antipodes. The insect-enemies behave to the earwig's eggs as familiar ichneumon-flies do to caterpillars. They pounce on them and lay their own eggs in the earwig's, which obviously means a reduction of the pests. The anti-earwig parasites have parasites that prey upon *them*, for as the old doggerel has it, 'Great fleas have little fleas upon their backs to bite 'em.' But the Rothamsted nurses have been very successful, and it will be interesting to hear how their charges behave themselves when they are let loose in New Zealand. Will they attend to the earwig business, or will they die of homesickness, or will they find new enemies that are too strong for them? It will be interesting to hear the result, but the point is that investigators like those at Rothamsted are more given to looking and doing than to waiting and seeing; and that this anti-earwig experiment is on a line with others that have already proved successful in a high degree. This is the biological control of life.

MALARIA AND ROAD-DUST.—As the microscopic animal (*Plasmodium*) that causes malaria is carried from a malaria-infected individual to a fresh victim by certain kinds of mosquito (*Anopheles*), the surest protection against the disease is to prevent the breeding of mosquitoes. The larvae live in ponds and pools, and they can be balked (*a*) by drainage and ditching; (*b*) by a film of oil which prevents them from gripping the surface of the water with their respiratory tube—the result being that they drown; and (*c*) by the introduction of little fishes, like minnows, which devour the 'wigglers'—a method obviously well suited for reservoirs of drinking-water. The efforts of

the Rockefeller Foundation have recently shown that dusting foul breeding-places with a powder composed of one part of Paris green, also known as Schweinfurth green, and a hundred parts of sifted road-dust is as effective as it is cheap. Originating with the United States Public Health Service, the plan has been recently tried with success in Italy and elsewhere.

MOTOR CARS AND TROUT-FISHING.—Especially in the world of life, everything is linked to something else. Thus there are demonstrable linkages between water-wagtails and successful sheep-farming, between the sunshine record and the supply of mackerel at Billingsgate, and between cats and the incidence of the plague in India. There are some who would even connect humble-bees with the doggedness once characteristic of John Bull, and little fishes with the decline of the glory that was Greece! Some of these Natural History conundrums may be far-fetched, but there is no doubt that hundreds of the vital linkages are very real and very important; and we wish to refer to the linkages between 'motor cars and trout-fishing.' We refer, of course, to the sad fact that many rivers are becoming less and less clean, and that the fouling is in part due to the influx of tarry materials from roads which have been modernized in adjustment to motor traffic. There is a very matter-of-fact linkage between motor cars and trout-fishing, and there is no doubt as to the increased pollution of certain rivers within relatively recent years. One of the most expert anglers in Britain, Mr. J. Arthur Hutton, of Alderley Edge, who knows his salmon well, declared in evidence recently given to the Privy Council that the situation was becoming worse every day, and that, if nothing were done, it was only a question of time before most of the salmon rivers of this country would be practically destroyed. Besides the washings from tarred roads, there are the pollutions from sewage and the products of manufactures, including the effluents from recently established beet-sugar factories.

The damage is not merely to sport and to beauty, but to the whole life of the river, with its far-reaching interrelations. Farm stock may suffer from drinking the poisoned water, and human health may be depressed by the foul smells. But not less serious is the loss of wealth, for when our country should be straining to increase its hold on the natural energies—which is what wealth means—the reverse is taking place. We might easily have more plentiful and cheaper salmon—a most excellent food—and we are allowing ourselves to have less and to pay more for it. The economic aspect is very serious, for Great Britain and Ireland produce more salmon than all the rest of Europe. The annual yield is reported as six thousand tons of fish, which means a cash value of a million and a third.

In his reply to an influential deputation, the Lord President of the

Council emphasized the need for more science, which might discover, for instance, some way of avoiding the pollution and poisoning of the rivers, without expecting too much from the manufacturer, the road-maker, or the municipalities. On the same lines is a report by Dr. H. C. Redeke, published by the International Council for the Exploration of the Sea. It deals scientifically with the pollution of rivers, and the relation of this to fishing. It begins by pointing out the deplorable fact that some rivers, from source to mouth, have ceased to be habitable by salmon and trout, while others are locally so much polluted that there are long reaches in which fish-life is practically impossible.

What are the causes of pollution? They may be classified as: (1) sewage and domestic effluents from towns and villages; (2) industrial waste; and (3) road-washings. The heterogeneous mixture called sewage is mainly injurious because the contained organic and ammoniacal matter becomes more or less completely oxidized by bacteria in the river, and this oxidation uses up much of the oxygen dissolved in the water—so much, often, that the fish have not enough wherewith to breathe. At a certain distance below the sewage intake the river has righted itself again, but this is of little avail if one intake succeeds another. Investigators distinguish a **poly-saprobe** zone where no fishes can live; a **meso-saprobe** zone which carp, tench, sticklebacks, and the like can endure; and an **oligo-saprobe** zone where salmon and trout are moderately happy. The sewage may be dealt with: (1) by dilution in the river itself; (2) by delay in sedimentation, precipitation, and septic tanks, of which there are many types; (3) by irrigation and filtration on land which decreases the putrescibility, especially in the 'activated sludge' method where the help of enormous numbers of bacteria and protozoa is utilized; and (4) by disinfection with sodium-hypochlorite or the like, which kills off bacteria of intestinal derivation without any danger to fish-life. It seems that the problem of domestic sewage disposal has been in great part solved, and that there is no excuse along this line for allowing clean rivers to become poisoned and poisonous.

Industrial waste is often injurious because of the presence of organic matter, as from beet-sugar factories, potato flour and starch manufactures, dairy industry, brewing and distilling, slaughtering, flax-retting, and so on. Or there may be a mixture of organic and inorganic matters, as in the waste from leather trades, cellulose manufactures, textile processes, and so forth. Or the injuriousness may be due to the presence of inorganic matter—e.g. from gas works, metal works, the artificial silk industry, the working of salt deposits, and the washing of ores. Here the injurious stuffs are so varied that they require in many cases special treatment, which raises obvious difficulties. 'On the other hand,' says Dr. Redeke, 'a certain lack of interest on the part of

the manufacturers cannot be denied, and sometimes, although there is a way, there is no will.' A general rule seems clear—that industrial waste should not be discharged into sewers without previous treatment; indeed, there are some wastes that cannot be purified along with domestic sewage.

It is said that friendly conference and open-minded experimentation have led in some places to the use of road material which is quite effective for its purpose yet does not yield poisonous washings. Thus, some non-poisonous material, such as bitumen, can be substituted for what is injurious. Of other places it is said that natural filtration of the road-washings has been economically effected.

How are the fishes affected? We have referred to the reduction of the amount of oxygen in the river during the purifying work of the bacteria, but the introduction of domestic sewage and industrial waste may also imply the presence of poisoning substances that act directly on the fishes, or on the even more sensitive small fry on which they depend. It seems to have been proved that the saponine and sapotoxine in effluents from beet-sugar factories act directly on fishes, while there are other substances, such as even small quantities of sulphuric acid, iron hydroxide, and ammonia, which are very prejudicial to small molluscs, crustaceans, insect larvae, and the like, on which many fishes depend. Fishes are badly affected by substances like naphtha, benzene, coal-tar, and even extract of sawdust. It is because of products connected with tar that road-washings are in many cases so lethal.

Great progress has been made since the middle of the nineteenth century, and every one is grateful for the Rivers Pollution Prevention Acts of 1876 and 1893, the Salmon and Freshwater Fisheries Act of 1923, and so on, but the point is that new industrial wastes, such as those of beet-sugar effluents, and new methods, such as the employment of tar in road-making, have brought new dangers to the rivers. Assuredly it should not be beyond man's wit or will to prevent a clear stream, as rich in life as in beauty, from becoming a poisoned and poisonous open sewer.

STRUGGLE AND MUTUAL AID.—Since Animate Nature depends on chains of reincarnations or re-embodiments, there is bound to be much stern struggle. Skua-gull chivies herring-gull and forces it to disgorge its captured fish; the herring-gull may catch a mackerel; the mackerel battens on small crustaceans; and these may feed largely on microscopic infusorians. As we have seen, all fishes are in the long run animalcule-eating.

As Nature is constituted, there is bound to be much struggle for existence of a crude and sanguinary type. But we need not make ourselves miserable over this, for in most cases the death of one animal

at the hands of a predatory neighbour is all but instantaneous; the standard of pain is usually very low; and there is a great deal to be put on the other side of the account. We must insist that the struggle for existence is often a subtle endeavour after well-being, or after such luxuries as a fifth mate to add to the harem, and it may consist of responses to the physical environment rather than of competitive wrestling with rivals.

There is no denying that Nature is sometimes 'red in tooth and claw,' but we tend to hear too much about this aspect, and too little about other reactions to difficulties which take the very different form of mutual aid.

Thus the world of life is crowded with fitnesses or adaptations which give offspring a good start in life. Before and after birth the young ones are often nurtured and protected in very effective ways. As this **parental care** is exhibited by many plants as well as by animals, so we must not make too much of it from the psychological and ethical side. But it is real enough. The digger-wasp does not usually survive to see the offspring whose early meals it has secured with diabolical ingenuity by storing paralysed caterpillars beside the developing egg.

While we must try to avoid reading the man into the beast, we must not go to the other extreme of denying all psychological interest to the apparently courageous way in which a male stickleback drives off a trout from the vicinity of the nest which he guards. A mother stoat leading her family will stand up to the gamekeeper and his dog. In his *Descent of Man* Darwin told Brehm's story of the big baboon which went back to the 'sportsmen' and their dogs to rescue one of the children that had been forgotten in the retreat. The world is fnll of such incidents.

On another line are the heights of **conjugal devotion.** The male hornbill will wear himself to a skeleton in collecting food for his mate who is imprisoned in a hollow tree; and, by and by, for the family as well. Mr. Hudson told the pathetic story of the broken-winged goose that set off on foot when the migratory custom called them southwards from their winter quarters on the Pampas. The gander was torn between two impulses—on the one side to join those of his kind flying overhead to the southern breeding-places, and on the other side to keep beside his mate. He would rise in the air and call her wildly; he would then return encouragingly to her side as she continued her journey afoot to the Magellanic Islands.

We cannot make sense of the story on apsychic lines. We think Hudson's sentiment is truer to life: 'And on that sad, anxious way they would journey on to the inevitable end, when a pair or family of carrion eagles would spy them from a great distance—the two travellers left far behind by their fellows, one flying, the other walking; and the

first would be left to continue the journey alone.' The realm of animal life is crowded with this sort of devotion.

If we turn a loose stone upside down by the wayside we sometimes disclose a large community of ants, and the striking fact amid the tumult of the catastrophe is that the workers instinctively try to rescue the cocoons, the post-larval stages in the life-history. It is not a question of 'safety first'; the rule is 'children first.' But these workers are risking themselves for children who are rarely, if ever, their own, though they may be daughters of the same queen. Similarly in the elaborate nurture of the beehive, the wasps' nest, and the termitary, the workers display an instinctive sympathy which has spread beyond the parento-filial relation to kin-sympathy.

Kropotkin wrote a fine essay long ago on 'Mutual Aid among Animals and among Men,' and he worked up his case through the inclined plane of gregariousness to true **animal societies.** Besides the instinctive sociality of ants, many bees, many wasps, and all termites, there is the intelligent sociality of such birds as rooks, cranes, and parrots, and of such mammals as beavers, prairie-dogs, wild horses, and monkeys. One of the conditions appears to be rapid increase, and another the economic possibility of large numbers living together and obtaining food by methods which do not imply solitary effort. Thus social spiders are all but unknown. But there are subtler intrinsic conditions, such as a natural capacity for self-subordination and an inborn feeling of kinship.

Let us sum up the manifold advantages of social life among animals: (1) Union is strength, for while the individual ant is contemptible, a horde of ants is a terror. (2) There is increased efficiency of achievement, for a company of beavers can cut a canal which a pair of beavers could never finish. (3) There is greater possibility of permanent products, such as a beaver-dam or an ant-hill. (4) There is the possibility of a high degree of division of labour, which makes for success. (5) The social *milieu* favours the growth of intelligence. (6) It also makes for a socially-approved self-subordination and a habitual other-regarding, both of which have a deep ethical importance. (7) Lastly, the stability of a society allows of tentative new departures that an individual could never risk.

What Kropotkin did not realize was that there are risks as well as rewards in animal societies. The robust all-roundness and independence of the each-for-himself type is apt to be lost. Self-subordination and division of labour may go so far that semi-pathological types arise, such as the soldier-termites who cannot feed themselves. The society may be so strong that sinister conditions become possible, as among the slave-keeping ants, where the 'masters' are unable to forage or even to take food from the spread table.

There may be, as in ants and bees, the horror of a reproductive caste and a vast industrial multitude of sterile females. What Nature tells us is that communal and individualistic policies are both effective for different ends and in different conditions, and that both of them may be pushed to a dangerous extreme. What must be clearly understood, then, is the need for keeping to the broad facts when we speak and think of the struggle for existence. It includes all the endeavours that are made, whether consciously or not, to meet environing difficulties and limitations, whether these handicap the organism's self-preservation or its race-continuance.

The Secret of Sex

What is meant by sex? We speak of a 'sex novel,' a 'sex problem,' a 'sex complex,' and so on; but strictly speaking, the word refers to the quality of maleness or of femaleness, and the central meaning of this is a secret.

Why is a peacock so different from a peahen, or a ruff from a reeve, or a bull from a cow, or a man from a woman? In many languages the two sexes of the same kind of animal are called by quite different names; and occasionally naturalists have unwittingly described the male and the female of the same animal as belonging to different species. It is, indeed, often difficult to believe that the resplendent male bird of paradise is the mate of the plain, soberly-coloured female. In mankind women are obviously the more decorative, but among animals it is usually the other way round.

Sometimes the differences between the sexes are extraordinary. There is a famous Japanese crab, called *Macrocheira*, or big-handed, which can span eleven feet with its great claws outstretched. His mate, the female, is much smaller and without big hands.

With some spiders the male is a nimble dwarf, quick to evade the somewhat capricious temper of his much larger desired mate. In some cases the almost incredible disproportion in size is comparable to what we should see if a man six feet in height and 150 lb. in weight were to marry a giantess ninety feet high and weighing 200,000 lb. What do all these differences mean?

We must correct the impression we get from these contrasts, however, by remembering that in many birds—skylarks, kingfishers, and rooks, for instance—the sexes are nearly indistinguishable.

Similarly, in many mammals the two sexes are often indistinguishable without dissection. The sexes are very much the same in cat, mouse, rabbit, and hare. So we see that the secret of sex must be something that applies to cases where the males and females are very closely alike and to cases where they are very different. And it must

apply to the threads of mould on stale bread as well as to birds of paradise.

Sex oddities are very suggestive and show us that sex is a constitutional quality with many different outcrops. Metaphorically speaking, it looks as if Nature had sometimes played tricks with maleness and femaleness, so that their diverse expressions come to suit all sorts of quaint situations. Dr. Tate Regan, the distinguished Director of the British Museum of Natural History, tells us of several tiny fishes, related to the anglers, among which the female carries about a pygmy male. In one species she carries him between her eyes on the front of her head; in another species he lives under her armpit, if fishes have an armpit. The blood-vessels and tissues of both fishes join, so that he is a parasite as well as a pygmy. Yet she cannot do without him, for he fertilizes the eggs.

Now this would look like a joke on Nature's part were it not so adaptive. For these horned anglers live in what are called the mid-waters of the ocean, between the limit of the illumination from above and the great abysses—a thinly peopled zone. As encounters of separate sexes would tend to be few and far between, those types have survived which could get the dwarf males to fasten on to the females early in life. There was survival value in the strange habit of carrying about pygmy parasitic males.

For the purposes of our argument we must swing back from this intriguing oddity to cases like starfishes and sea-urchins. There is a British starfish which produces two hundred million eggs in a year, while the male produces at least ten times as many sperm-cells. Yet, despite this accentuated sexual reproduction, the males, so far as we know, cannot be distinguished from the females without microscopic examination of the germ-cells which they respectively produce. The same is true of the common sea-urchins, the sexes being externally identical.

What then is the quality which makes one individual an egg-producer and another a sperm-producer? That is the radical question.

To the genius of Sir Patrick Geddes we owe a **theory of sex** which has never got its deserts. We expounded it along with him in *The Evolution of Sex*, published in 1889, quite a long time ago, and we believe in it still; though it requires to be supplemented, e.g. by the Mendelian Theory (see p. 987).

In all living creatures there are biochemical processes of up-building and down-breaking which see-saw with one another. In a green leaf in the sunshine there is a building-up of sugar and the like—the most important chemical process in the world, for part of the energy of the sunlight is used to make carbon-compounds from carbon dioxide of the air and water of the soil.

This is a good instance of up-building; and plants thereby live so much above their income that they make plenty of food for themselves and for vegetarian animals as well.

But when an animal moves about and does work it is burning away some of its carbon-compounds, so that energy is set free, somewhat as in an engine; and there is a production of carbon dioxide and water as end-products. This illustrates the breaking down of the complex into the simple.

Now Geddes's luminous suggestion is that maleness means a kind of constitution in which the ratio of down-breaking to up-building is relatively high and the chemical routine of the body more intense than in femaleness, where the up-building processes are relatively in the ascendant. On this theory the initial difference between the egg-producing female and the sperm-producing male is a constitutional difference in what we may call gearing. The true inwardness of sex is a difference in the rate and rhythm of the biochemical routine of the tissue. The female is relatively—it is all a question of ratio—the more constructive, whence her greater capacity for sacrifices in maternity. The male is relatively the more disruptive, whence his usually more vivid and often shorter life, and his explosive energies.

One of the arguments in favour of this theory is that it brings maleness and femaleness into line with an alternative that we find cropping up all through the world of life—between very liberal expenditure of energy and a more conservative habit of storing. Take the contrast between the usually active birds and the usually sluggish reptiles, between the Open-Sea jellyfish and the sedentary coral, between the average animal and the average plant. It looks as if this branching of the ways were of wide occurrence throughout the whole animal kingdom; perhaps sex is an almost universal expression of a fundamental alternative in variation.

But let us pass to another aspect of the problem. We cannot begin to understand sex in higher animals or in ourselves unless we know something about hormones, the 'chemical messengers' of the body. **Hormones**, as we have explained, are transparent fluid substances, manufactured in backboned animals by certain ductless glands, such as the **thyroid** (beside the Adam's apple of the throat), the **suprarenal** (close to the kidneys), and the **pituitary** (attached to the under-surface of the brain). Since these glands have no ducts, the hormones they produce in small quantities are swept away by the blood-stream and are carried to all parts of the body. Their influence on the life of the body and of the mind is powerful.

The antlers of a stag, the decorative plumes of a cock bird, the swollen first finger of a male frog, the gorgeous colours of a male stickleback, the swelling udder of the cow, the change of mood in

the adolescent, are all prompted by hormone messengers from the sex-organs.

Besides the essential quality of maleness or femaleness, there are often secondary sex-characters, such as attractive decorations in the male and maternal fitnesses in the female. These may be called the masculine and feminine characters.

Now modern investigations go to prove that in animals with separate sexes all the germ-cells carry, as part of their hereditary make-up, a complete set of both masculine and feminine characters. Which of the two will find expression in development will depend on the bias of the fertilized egg to maleness or to femaleness, including, of course, the subsequent influence of the hormones from the reproductive organs.

On our physiological theory of sex it is readily intelligible that the maleness or the femaleness may not always be equally emphatic, and that this may allow of some combination of masculine and feminine features in the one animal. (But see also p. 998.)

The extreme form is seen in cases where the sex changes in the lifetime. The hagfish seems to be male until it attains a certain size, about eight inches long, when it becomes a female. The slipper-limpet is first male, then female, with a two-sexed phase in between. The same is true of a little starfish called *Asterina*.

Numerous backboneless animals, such as earthworms, leeches, and snails, have the two sexes always combined.

Again, there are cases where a female bird, having had its ovary removed by disease or by operation, then puts on masculine characters, as in its plumage.

These masculine characters normally lie latent in the female bird —probably kept latent by the influence of the hormones from the ovary —but if this repressing influence is inoperative, the duck may put on a drake's plumage at the next moult, and a hen may crow like a cock— cases which might be used to support our physiological theory.

Hitherto we have confined our attention wholly to the body, but we should never puzzle over sex, even for a little, without remembering that it is the root-work of a growth whose flowers are those of love, while its fruits are often seen in a happy family. It is one of the big facts of Evolution that from very humble beginnings sex rises in the animal kingdom to fine expressions, as in the courtship and comradeship of birds. To physical attractions there are added emotional enhancements, aesthetic appeals, and joyous partnerships, which are sometimes loyal for a lifetime. So with man most of all, but while the flowers of human love depend in part on the strong roots of sex, these sometimes require pruning if the flowers are to be of the finest.

ANIMAL COURTSHIPS.—In the lower reaches of the animal kingdom there is not much mating in the strict sense. Countless eggs are

liberated by the female into the water, millions in the case of some starfishes; still more multitudinous sperms are liberated by the male into the water; the fertilization of the egg-cell by the sperm-cell is fortuitous, and in a large percentage of cases it fails to occur. Yet the race is continued in full strength because Nature works with such a big margin.

One cannot draw a firm line between the 'spawners' and the 'maters'—thus both are illustrated among fishes—but it is probably fair to say that one of the trends of organic evolution is towards economizing in the number of offspring. The economy is peculiarly valuable when it prolongs the individual life, which is apt to be fatally sacrificed in cases of over-prolific multiplication. Automatically, in the struggle for existence, the more prolific types of animals would at first tend to survive; but when the footing was firmer, the nature of the sieve would change, and survival would be the reward of economy in reproduction.

Those tapeworms survived that varied in the direction of producing enormous numbers of eggs, and some produce eight millions. Yet the golden eagle is at present holding its own in Scotland although it is a slowly maturing bird and lays only two eggs in a year. But our argument must continue, that if the number of offspring is to be greatly reduced, then there must be at the same time an evolution of those vital arrangements that make fertilization secure and the welfare of the young also.

Thus we get a glimpse of the meaning of mating and of the small family; but it must not be forgotten that these may also express something of the inner or mental life which gradually increases as life advances. Mating activities and family life are not merely the conditions that make it possible to economize in multiplication, they are the expressions of a heightened pitch of life.

Spring is the season of love-making, and we may observe a great variety of ways in which mates are won. We must, of course, presuppose: (*a*) an **internal periodicity** which awakens sex and sends the sex-hormones coursing round the body in the blood, and also (*b*) an improved **external relation** of our part of the world to such sun-rays as the earth can intercept. But given sex and sunshine, the animal seeks for a mate. In an enormous majority of cases *he* seeks for *her*.

Simplest, perhaps, is the method of restless roving on the male's part until he comes into contact with a female. Even the hard-shelled crabs search and then touch. The first step may be awareness of the other's presence, but we must beware of using at low levels any big word like 'recognition.' The next step is some thrill. The **touch** serves as an exciting stimulus. Then may follow a great variety of elaborations—strokings, tappings, caressings, fondlings, with their

highest subtlety, perhaps, in the vibrations by which some cautious or timid male spiders announce their presence to a possible mate. The vibrations are transmitted along a silk thread, and a retreat is readily possible if the advance is resented.

In some moths the females have minute odoriferous glands on their wings, and delicate arrangements for distributing the scent. This serves as a strong attraction to the males, who may from a mile off fly head-on against the wind-borne scent. What a far cry from this to the way in which some male mammals leave olfactory signals of their proximity! There is no doubt that some animal scents serve as powerful attractions.

The first use of the voice, as may be inferred from the croaking frogs, was as a **sex-call**; and it is interesting to think of its crude beginnings and then of its climax in the nightingale's serenading. It is not, of course, always pleasant to our ears, as caterwauling illustrates, but it serves in most cases as an excitement and an appeal. At its highest levels in bird-song it is also an artistic expression of high emotion. As is well known, the songsters are usually the males, but we must not forget that in some birds, as in skylarks, there is a response on the female's part.

Over a wide range of animal life there is an **appeal to the eyes** in courtship. Among the luminous beetles that we call fire-flies, the males send their light-signals from the air to the also luminescent females who sit among the grass or herbage. In our glow-worms the wingless female in her dell of dew is more luminous than the flying male. Sometimes colour seems to count for much, and so does a showing-off of decorations. Among birds there are often special love-antics in the air and special dances on the ground. Some of the male spiders, who have many queer ways, are also great dancers. In all cases the first aim is to interest the female, which is not always easy; and the second aim is to excite her, which may require long wooing. Occasionally, for Nature has tried everything, the female does the courting.

Subtlest of all, we think, is the occasional offering of gifts, which seem to have some associative or suggestive value. Thus there is an offering of mouthfuls of water-weed by the great crested grebe. A male spider sometimes gives his desired mate a titbit wrapped up in silk. The male in some *Empid* flies spins an ornate capsule which he offers to the female as a present!

ANIMALS AS MATES.—It is rather absurd for man to look to animals for moral or social guidance. Not only are they so heterogeneous that they afford illustration of a great multitude of ways all of which have been rewarded with survival, but animals are not in the strict sense moral agents. That is to say, they do not deliberately control their activities in reference to general ideas or ideals. They

are creatures of impulse; they may show good behaviour, but they do not show moral conduct, as man sometimes does. The nearest approach to ethics is to be found among social animals, where respect is sometimes paid to public opinion and to tradition, and among domesticated animals, especially dogs, where behaviour is sometimes controlled in relation to man, who functions as a kind of external conscience. The affectionate restraint that a domesticated animal sometimes shows in reference to the children of the household is often beautiful.

Our point is that while many animals have many virtues, only a few approximate to morality. Moreover, man has in his own history ample materials for continuing to develop his moral code. He need not go to the ants for guidance. Yet there are in the ways of animals what might almost be called diagrammatic warnings and suggestions.

The seamy side of the beehive or the ant-hill with its reproductive caste, its vast proletariat of repressed females, and its non-productive males or drones, is familiar. The cuckoo is a flagrantly non-maternal type; the female phalarope is very masculine; the cock rhea is very motherly; the bull seal is a patriarchal polygamist.

But the cock birds that continue to sing after the end of the courting and honeymooning are patterns to better-endowed lovers, and the elaborate tuition that the mother otter gives her cubs is rich in suggestiveness even to experts in education.

For the animal world we must continue for a time to use the word 'monogamy' somewhat guardedly, for there are not very many observations to prove that mates remain together year after year. What is certain is that many couples remain together for the breeding season; and if the critic objects that this does not prove their mutual faithfulness, it can only be answered that cases of unfaithfulness are rarely observed. As in civilized mankind, so in many animals, the normal sex-relationship is monogamous.

In his valuable *Social Life in the Animal World* Professor Alverdes gives the following examples of monogamy: gorillas (for many years at least), chimpanzees, some monkeys (though gregarious), guinea-pigs, Patagonian cavies, and even rabbits (though the male is sometimes a rover). To this list should be added a number of solitary carnivores, such as fox and otter. Some whales live in pairs, and the mating of the rhinoceros is almost certainly for life.

Some solitary hunters like jaguars have a severely punctuated sex season of only a few weeks, during which they are monogamous, but after which they separate as individuals, the young ones being subsequently cared for by the mother alone. The extreme solitariness of some of the carnivores large and small shows the potency of the economic factor, and should be contrasted with the gregariousness and

polygyny of seals, where the abundance of fishes takes the edge off the struggle for existence.

Another point is that, while promiscuity is rare, some phrase like seasonal monogamy must be used for cases like that of lions, among which there is usually monogamous faithfulness during the breeding season, though the partners are or may be changed every year.

All species of parrots, according to those who know them well, live in strict monogamy throughout their lives; and Alverdes reports that if one of the mates (e.g. among arara-parrots) is shot, the other not infrequently allows itself to be captured. Monogamy is very strict among swans, geese, cranes, coots, and many other birds, even when they are gregarious.

Alverdes writes: 'Penguins, herons, wild guinea-fowl, some species of sandpiper, sea-gulls, sea-swallows, auks, guillemots, parrots, bee-eaters, swifts, certain birds of prey, e.g. most of the vultures, ravens, starlings, some thrushes, the weaver-bird, many doves, ducks, cormorants, all are gregarious throughout the year, and live in monogamous unions for several years, if not for life. Even sparrows are monogamous.'

Some of the exceptional facts are very interesting. Thus, in the case of the African ostrich the cock arranges the nest, and shares the brooding with his mate—the ordinary monogamous régime. But as there are more females than males, the cock allows himself amorous adventures. The eggs of these unwedded females are deposited in already tenanted nests, often a very unsuccessful proceeding. Outside the breeding season the ostriches are of course gregarious.

As one would expect, cases of infidelity occasionally occur among normally monogamous birds, and on the part of both sexes. A female pigeon once mated is usually faithful, but this is not always true of the male.

The two big facts are, that monogamy is very common among birds as well as polygamy, and that the male takes a much larger share in parental duties than is usual among other creatures. Birds are rich in feeling, and there is a high standard of affection, as distinct from passion.

Our knowledge of intimate domestic affairs among the lower animals is very scrappy as yet, but it is safe to say that a great many creatures consort in pairs, and co-operate in parental duties. Monogamous mating, for the season at least, is known among beetles like the scarabees, in the water-spider, in a few fishes and frogs, and in more than a few reptiles.

When we take a broad Natural History survey of the occurrence of monogamy and polygamy we are bound to conclude that both usually work very well, but that monogamy favours the evolution of the finer feelings.

Parental Care

In some of the tribes of Central Africa the mother carries the young child on her back or on her side all the day long. As she works in the field, or milks the cows, or goes about the hut, she has the baby always with her, and the child often clutches hard. So some of the opossums that have no pouch carry their young ones about with them, the tail of the youngster curled like a tendril round the tail of the mother. Sometimes there are six young ones holding on to their mother—a cheerful crew. How different from this—and yet the same—is the sight of the hippopotamus in the Nile with a youngster astride her neck! The mother monkey often carries her child from tree to tree, and the father sometimes gives her a rest by taking his turn.

Still more daring is the mother bat, who flies in mid-air with her offspring clutching her breast with its thumbs and closing its tiny front teeth on the curiously roughened hair. It is hardly necessary to say that the bat has rarely more than one offspring at a time. One is enough for a flying mother to carry about; and the small number also indicates plainly that bats are very safe in the struggle for existence. In the case of typical marsupials like kangaroos the young ones are born in a very helpless state, as it were prematurely, and they creep (perhaps with the mother's assistance) into an internal skin pocket which develops round about the milk-glands. The mouth of each young one closes over a teat, which then swells a little, and as the young one is at first unable to suck, the mother by means of special musculature injects the milk into its mouth. One might think that the milk would sometimes 'go down the wrong way' and drown the offspring, but there is an interesting adaptation to prevent this. The glottis or opening of the windpipe is shunted forward to meet the posterior opening of the nasal passage, so that air is borne along a continuous tube to the lungs, and the milk is kept to its proper place—the gullet. By and by the young marsupial gains strength, it pokes its head out of the pocket and looks around, it jumps out altogether, it clambers in again when danger threatens—an altogether quaint performance.

In illustration of maternal care among animals it is natural to begin with carrying the young ones about after birth, for this is a sort of prolongation of what is true of many mother animals, that they carry the young ones about *before* birth. This 'viviparity' is characteristic of mammals, but it is also seen in some reptiles, such as the adder, in some amphibians like the Alpine salamander, in some fishes like the viviparous blenny, in insects like green-flies, in the primitive *Peripatus* (linking worms to insects), which carries its young for about a year before birth, and so on downwards to simple creatures like some of the

sea-anemones. But even among animals that lay eggs which are hatched outside of the body there is often a carrying about of the youngsters. The Surinam toad has a big family in skin cradles on her back; the father sea-horse carries his family in a big breast-pocket. The young crayfishes shelter under their mother's tail, and hang on as she swims, and the brook-leech, so common under stones, has often a family clinging on beneath.

There is no hard-and-fast line between carrying the eggs about and carrying the young ones. In one crustacean the eggs are sheltered in a brood-pouch, and the young ones swim away as soon as they can, the mother paying no heed. In another crustacean, not distantly related, the young ones return to the protection of their mother after they have made excursions on their own. The wolf-spider (*Lycosa*) carries her eggs in a cocoon, and after the young ones are hatched they cling to her body in 'a squirming mass.' Professor Holmes says that she gives them no particular attention, and that 'it is doubtful whether her maternal care goes further than a good-natured tolerance of her living burden.' But it is probably safe to say that maternal care has one of its roots in prolonged attachment between mother and young.

When an animal can carry its eggs or its young ones about with it, that is making sure. 'Only sheer force will take them from me,' the mother says; 'I will die rather than give them up.' But it is often impossible to carry the family about, so we naturally pass to cases where the eggs are laid and guarded. Even in the same order—e.g. spiders—the two methods may be illustrated. As we rest on a summer holiday among the heather we may see a mother spider hurrying past with her cocoon held beneath her body and sometimes bound to her by silken threads. This cocoon is very different from the silken bag which a caterpillar makes around itself when it is going to change into a moth; the cocoon of a spider is a silken bag made by the mother to hold the eggs and by and by the young ones. Some spiders, as we have just said, carry the cocoon about and will not readily let it go, but others leave it in a more or less safe place. Bramble leaves are sometimes bound together with silk, and if we open them gently we find inside a silken cocoon or, it may be, several. Other kinds are hidden under loose stones or bark. We have found a pretty one which is not hidden at all, but is hung like a white bell, closed at the mouth, from a twig of heather. But our point is this, that in addition to making the cocoon and carefully disposing of it, the mother spider sometimes remains beside it, guarding it vigilantly. The true water-spider (*Argyroneta*), with her sub-aquatic web in the shelter of which she deposits her eggs, is not content to leave them there, but watches them with diligence. The trap-door spider sinks a shaft in the earth, plasters the interior smoothly, and makes a lid of clay with a silken hinge—all for the sake

of the bunch of eggs stowed away in a far corner. But she is not content to leave them; in some cases at least she remains on guard and holds the trap-door shut!

There is a strange animal, called *Galeodes*, a distant relative of spiders and scorpions, that lives in dry places in warm countries and is very poisonous. In the case of the species that frequents the Steppes of Turkestan, we are told that the mother excavates a shaft, mostly horizontal, in the ground, and lays about a hundred eggs in its recess. These hatch out in a couple of days, having been developing beforehand within the mother's body; but the young ones are not strong enough to face the outer world. So the mother mounts guard in the hole, and stays there fasting for five weeks. Then she lets her family go, and has a well-deserved meal. There is no end to these stories.

One does not associate an octopus or devil-fish with the gentler virtues, but this is mere prejudice. The mother attaches her eggs to a solid object below the surface, and returns to them at intervals to squirt water over them from her funnel. They are, of course, always bathed in the sea-water, but the forceful squirting drives off particles of mud and also promotes good aëration. This is a particularly interesting custom, for it occurs again among the quite unrelated true fishes, such as the lumpsucker already described (see FISHES).

We like to dwell on cases where the mother or the father lingers about the place where the eggs have been deposited. It suggests another root—or should we say bud?—of parental affection. We see it among fishes, amphibians, and reptiles, and does it not point on to brooding? The slippery gunnel or butter-fish on the seashore curves its body round the bunch of eggs; the male nurse-frog has the cluster of eggs fastened to his hind-limbs and remains quietly with them in the mud, going into the water occasionally to bathe; how gradually one is led on to the python, which anticipates the birds in actually brooding—encircling the eggs in its massive coils.

Every one associates nests with birds, but the nesting habit has a much wider range. It is a 'mothering' adaptation, tending to secure the safety of young ones that are at first relatively helpless. W. H. Hudson tells us that when the shepherds are moving a great flock of sheep from one part of the Argentine Pampas to another, a lamb may be dropped by the way. The mother rests a little, the new-born lamb staggers to its feet and has a drink, and long before the flock has passed the two of them are able to join in. Every one has seen how quickly a foal is able to totter along beside its solicitous mother—a useful quality in animals that originally lived as nomads on the plains. In such cases there is obviously no need of nesting, but we have only to pass to the not distantly related deer to find cases where the young are unable to move about for several days after birth. The

mother hides her offspring in the thicket, and this is half-way to a nest.

Amongst the branches of the tree, or where the main stem forks, the squirrel makes a large nest of moss and twigs, and there the young are nurtured. The nest is often conspicuous, for the squirrel has few enemies. It might be said that the squirrel's nest differs from a bird's nest, since the mother squirrel does not brood, but that is a distinction without much difference, since there are long quiet times of suckling the young. Should danger be very pressing, in the shape of a woodman, for instance, the mother may shift her young, carrying one at a time in her mouth.

Of nests at lower levels than birds and mammals—*nests without brooding*—there are many instances: the tree-frog's leaf nest suspended above the water, with a floor that gives way at the appropriate moment; the nest made by the male stickleback for the eggs of his several wives; the stone nest of the lampreys in the river; the hanging paper nest of certain wasps; the nest of the humble-bee in the mossy bank. But we must not be led off on this interesting side-track.

There is great variety in the ways in which the safety of the young is secured. The fact seems to be that the well-being of the young is to the mothers as preoccupying a problem as self-preservation. Unlike the rabbit, which secures safety by burrowing, and brings forth its young at a blind and naked stage, the common hare has her resting-place on a site from which she can get visual, auditory, and olfactory news of the country round about. But how effective is the simple device of taking a long leap out of the 'form' and into it again on her return from feeding, *for thus the scent is broken.* A hare has usually two leverets, for the sake of which she will fight—and beat—the weasel. If the fox is beginning to find out her home she will shift the youngsters by night, and some authorities say that when the mother has four leverets instead of two, she takes two of them to a second 'form,' not risking all her eggs in one basket. In a sense it is fair to call the rabbit a nest-maker, for there is a bed in the burrow that is made comfortable with the rabbit's own wool, and there the young ones are born. Our point is simply that the hare—the rabbit's first cousin—attains the same end of family safety by means altogether different.

Every nest-making is a more or less clear anticipation of what the young ones will require, but among insects there is often a much more elaborate preparation. One example must suffice. The *Sphex* wasp makes her burrow in the bank, she deposits an egg in a recess, she sets off to find provender, she meets a cricket and stings it twice in a ventral nerve-centre so that it is paralysed; she drags it to the mouth of the burrow, and lays it down for a moment while she dives into the earth to see that there has been no intrusion or interference; she comes up

again and deftly pulls in her booty; she lays it beside the egg, reascends, and flies away. The same thing is done again and again, and then the mother dies. When the Sphex grubs are hatched they find fresh meat —the paralysed crickets—close at hand. The whole chain of events has now become securely enregistered in the brain of the Sphex wasp; it is a chain of instinctive actions; and there can be no clear anticipation of what the Sphex mother has never seen, namely, her offspring. There can be little doubt, however, that the instinctive custom was established ages ago when the mother Sphex *did* survive to see her offspring, and that there was in the establishment of the instinct a degree of awareness that has long since been lost. The tyranny of the maternal instinct is well illustrated by Fabre's experiment of removing the cricket while the Sphex was reconnoitring underground. She came up, missed her booty, searched for it, found it, dragged it to the mouth of the burrow, laid it down, dived in, and came up again—only to find that the cricket had been stolen once more. This happened forty times in succession; a ray of active intelligence—which the Sphex does not possess—would have broken the spell.

In some countries, such as Madagascar, the mother crocodile buries her eggs a couple of feet in the loose soil, where fermenting vegetable matter aids the sun in sustaining a temperature suitable for development. This burial means safety, but it must be awkward for an air-breathing animal to be born beneath the ground. What happens is this: the mother does not go far off, and when the young crocodile is ready to be hatched it utters a piping cry—a signal that the parent understands. She digs down and the young crocodiles are not buried alive.

What a strange book is opened when we inquire into the different ways in which wasps deal with their young ones! Some provide stores before the eggs are hatched, some bring their offspring fresh food every day, and some put a brew of chewed insects into the mouth of the grub and ask in return a drop of salivary juice—which seems to be an *elixir vitae*.

How quaint is the case of the fish called *Kurtus*, which lives in fresh waters in New Guinea! There are not many eggs, and the dangers are great, yet safety is secured. Round each egg is coiled a delicate filament which unwinds when the eggs are shed in the water. Quite automatically the filaments become entangled together and bind the eggs into a double bunch, like a double bunch of currants. At the breeding season a finger-like hook of bone grows upwards, forwards, and then downwards on the top of the male's skull; and just before the hook is becoming an 'eye' he rushes at the floating bunch of eggs, and gets them fixed on the top of his head. No place could be safer, and he carries them about till they hatch. Of course this is not *maternal*, but we must give the fathers a look-in.

Underneath the moss on an old wall we found a small squat insect almost as white as flour. It moved very slowly, as if half-asleep, and it seemed to have a 'trailer' behind its body, shaped rather like a broad shovel. When we looked into this trailer we found it was full of developing eggs. Where is the maternal voice not heard?

Those who live in the country know well that they must be cautious in going near a mare with a young foal. In her solicitude she is dangerous. Even a gentle creature may forget herself and kill her master whom she suspects of threatening her offspring. What really happens in an animal so long domesticated as the horse is no doubt a welling-up of an ancestral instinct from the depths of the unconscious. It is very instructive to learn that some Scotch cows transported to America hid their new-born calves in the bush while they grazed in the open—returning in a bound, as it were, to the custom of wild cattle.

We read of the rage of the she-bear 'robbed of her whelps,' but there is likewise rage when the young are merely threatened. Many carnivores show this, not only lions and leopards, but small creatures like stoats and weasels. In defence of its family the mother stoat will stand up to a man: there is not a particle of fear in its composition. We hardly wonder at the passion of the mother elephant with her offspring at her feet, but we can cap that near home when the mother hare leaps over the weasel intruding on the leverets playing in the light of the moon and kills him with a strong back kick. There are many instances of the *mater furiosa*.

The same is true of many birds. How vigorously the swans defend their nest, and how effectively the cliff-swallows unite to drive off the falcon! At lower levels, too, we see the same parental courage, as in the father stickleback, who rushes at intruders five times his own size; or in the mother spider, who will fight for her cocoon. On a side-track are the devices illustrated by lapwing and by fox, where there is a feigning of lameness or injury, which distracts attention from the young.

There are cases where maternal care seems conspicuous by its absence. What is one to make of them? There is no special difficulty with the 'spawners.' The frog deposits her thousand or more eggs in the shallow water of the pond, and cares no more about them. There are too many tadpoles to be looked after, and the race continues in spite of the huge infantile mortality. Nature does not support the superfluous—even when it is a virtue. But the way of the frog would not work in the case of the golden eagle with its two eggs, or of the bat with its single offspring.

Then there are cases where man makes a puzzle by failing to recognize the intellectual limitations of the animal. Many a female fish

will devour her own offspring if she comes across them in the water; but it is not to be supposed that she is in any sense aware that they are hers! We may set against this more than one case where the male shelters the eggs in his mouth. He fasts till they are hatched; but it looks like 'tempting Providence.'

In other instances, like that of Professor Whitman's passenger pigeon, which could not, or would not, retrieve her eggs though they were only a few inches off, the explanation is simply this: that in many animals certain parts of the business of life have in the course of time been 'handed over to instinct' so completely, and in natural conditions so effectively, that any disturbance of the routine non-plusses the animal altogether.

We recall one of Mr. Hammerton's true stories about a cow that was so grief-stricken by the death of her calf that she would not eat her food or give any milk. So they took the skin of the calf and stuffed it with hay and placed it before the bereaved mother. She was comforted, and licked the stuffed calf copiously; her appetite returned and her milk-giving. But as time went on she made a hole in the calf's skin with her caresses, and coming on the hay stuffing, ate it. Now it is fallacious to find any great difficulty in this absurd story, or in others like it. It would be erroneous to argue that the cow had no affection for her offspring because she was comforted by its stuffed skin; it would be equally erroneous to reproach the cow for its ignorance of bovine anatomy. At the same time we may admit that the brain of the domesticated cow is in a rather comatose condition.

There are many interesting cases where the instinct for mothering is so strong that it overflows to the children of quite different animals. Miss Frances Pitt took a new-born rat and, after putting it beside young kittens for a little while to get the appropriate odour, gave it to a nursing cat. It was accepted without demur, and duly suckled, licked, and nurtured as if it had been a kitten. When the rat became able to fend for itself it kept up its friendship for the foster-mother and used to pay her frequent visits. They continued to be on the best of terms. One day the rat came running impetuously into the room where another cat was lying, whose surprise was a spectacle! An interesting detail was that, though the foster-mother had been a good 'ratter,' she never killed another. One would like to know whether this fact could be generalized—whether a foster-mother in her subsequent life ever attacks the species of its *adopted* baby.

An extraordinary case of 'fostering' is that of a hen who sheltered two young weasels (which were extraneously fed by the observer), and got on very well with them, except when they bit her in searching for something to suck. The mothering instinct is strong.

Almost unique among backboned animals is the cuckoo, which shirks most of its maternal responsibilities, but this is a special freak —a telescoping of two whole chapters in the ordinary routine of instinctive parental behaviour. Among insects there are many approximations to this extraordinarily interesting deviation from the strait path of maternity.

Naturalists have given far too little attention to the education of young animals by their parents—usually by their mothers. It is not common, but it is probably of great importance when it occurs. For it corresponds to tradition and education in mankind—a way of entailing gains that do not form part of the organic or flesh-and-blood inheritance. Naturally enough we do not find examples of maternal instruction among those animals whose behaviour is almost wholly instinctive or hereditarily enregistered. Thus a young Sphex wasp is not in any way handicapped in the business of its life by being an orphan (its parents are always dead before it is hatched), for it has all its repertory of devices ready-made and inborn.

It is among mammals in particular, where intelligence is waxing and instincts are waning, that maternal instruction is highly developed. Take the otter, for instance, which we know so well through the lifelong studies of Mr. Tregarthen. The mother is a paragon of maternal care and a good educationist. She punishes her cubs, but she also plays with them. She teaches them the long alphabet of woodcraft—which sounds are trivial and which significant; when to press on and when to play 'possum. She gives them swimming lessons and diving lessons, and shows them how to catch trout and eel, frog and rabbit. She teaches them not to return to the kill, how to go home without retracing their steps, how to lie *perdu* beneath the bank of the river while the otter-hounds are nosing all over the place. Table manners have also to be taught, and they have a biological basis; thus frogs must be skinned before they are eaten, for the skin is as unpalatable as the muscle is delicious, and while the trout must be eaten from the head, the eel must be tackled from the tail. There is a long childhood and an elaborate schooling, and surely we have here one of the reasons for the otter's survival. The same kind of maternal instruction is given by stoat and by fox, and by various other mammals; likewise by some birds. It must also be remembered that the play of young animals is to some extent under the mother's eye, and that playing means an irresponsible apprenticeship to the serious business of life, a time for testing instincts and liberating intelligence.

The biological philosophy of the whole matter is not far to seek. The clash of life against environing difficulties and limitations brings about the struggle for existence. One way of coping with certain difficulties is to multiply so prodigiously that some members of the

species are almost bound to win through. This is the spawning solution. One of our British starfishes, *Luida* by name, has in a year two hundred millions of eggs, so that it operates with a big margin. Many worms and insects, fishes and frogs, illustrate this success of the prolific. It is, however, not given to every animal constitution to multiply so prodigiously, and other ways must be tried. Thus success in the course of ages has rewarded those animals that evolved in the direction of maternal care. Whether this maternal care is instinctive or intelligent, or both, or neither, does not matter at present; the point is that maternal care *pays*.

It not only secures survival, but *better* survival. Thanks to the parental care, the young ones get a good send-off on the adventurous voyage of life. Moreover, it is physiologically expensive and preoccupying to the mother to have a million eggs in a year; there is more chance of freedom and fullness of life when there are only a few. Thus we see that animals which have got beyond the spawning solution have a finer life. And if the critic reminds us of hens laying two hundred eggs in the year, we must remind him this is quite 'unnatural,' for the laying period in wild birds is very strictly punctuated. Or if we are reminded of the mammalian mother's burden while the young are still unborn, we can only answer that she is normally the better for it. Maternal care pays, and the premier place in the animal kingdom has been won by mammals which have developed it to the highest pitch. The very name 'mammal' strikes the note of mother. Surely they have their reward.

But there is more. If a fish has a million eggs, many of which become larval fishes, parental care is unnecessary, and it is obviously impossible. But fishes that have only a few eggs, like sticklebacks, for instance, must exhibit parental care, else they would have been long since wiped out. Now it is plain that fishes like sticklebacks and sea-horses are more interesting creatures than cod and herring. In higher reaches, notably among birds and mammals, it is clear that when the offspring are cared for, and when they are not too numerous to be known and loved, the result is not only success to the new generation, but an enrichment of the life of the old.

We have said too little in regard to the emotional aspect, but it is difficult to get at the inner spirit of the animal. Take this paragraph from Darwin: 'Rengger observed an American monkey (a *Cebus*) carefully driving off the flies which plagued her infant; and Duvancel saw a gibbon (*Hylobates*) washing the faces of her young ones in a stream. So intense is the grief of female monkeys for the loss of their young that it invariably caused the death of certain kinds kept under confinement by Brehm, in North Africa. Orphan monkeys were always adopted and carefully guarded by other monkeys, both male

and female.' We have seen a monkey mothering a white rat, even when itself afraid.

Here is what we may call not a vicious, but a *virtuous* circle. Prolonged infancy and childhood affords opportunity for perfecting powers before mistakes are too costly, and for making original experiments or testing new inborn promptings. But this prolongation of youth is only possible if there be strongly developed and enduring maternal (or parental) care. On the other hand, it is the prolonged association of the offspring with the parents that tightens the cords of love—that raises devoted care into affection. Evolution works in circles.

Looking backwards, what do we see? The carrying of eggs before they are laid is extended to carrying them afterwards. The care of the eggs is extended to the care of what comes out of them. Remaining about the egg cluster would naturally lead on to brooding, and this would lead to nests in which the mother may have some comfort and concealment. On a side-track are all the preparations that are made by insects for young which they do not survive to see. A fresh start is made when there is viviparity, when the mother brings forth a young one like a miniature of herself, a young one that has been for a longer or shorter time her partner, and flesh of her flesh. There is a gradual intensifying of care and protection, a forging of emotional bonds, a definite educational discipline, and sometimes a short period of co-operation. Finally, on the foundations of the family there rises the animal society.

SEA-HORSES.—There is some suggestion of the evolution theory in the old-fashioned belief that the living creatures of the sea are the counterparts of those on land. Thus we have sea-anemone, sea-cucumber, sea-lemon, sea-lily, sea-lion, sea-mouse, sea-spider, and so on down to sea-urchin. Some of the names are shrewd enough, such as sea-otter and sea-snail; others, like sea-leopard and sea-cow, are not very wide of the mark; and, of course, there are plenty of genuine sea-serpents. Of many of the names, however, it must be said that they point to very fanciful resemblances, for sea-butterflies are gasteropod molluscs, sea-mice are bristle-bearing worms, and sea-horses are true fishes.

Save a suggestion of the horse in the shape of the head and the arching of the neck, and a more remote suggestion in the mobile tail, there is little that is equine about these quaint creatures, which, in fact, are like nothing else either upon the earth or in the waters under the earth. They are a little like the knights on a chessboard or some of the dragons of heraldry; but they are the most 'kenspeckle' creatures in the sea, and that is saying a good deal. Chamaeleons come a close second on land, and bats in the air. Surely Nature must have smiled to herself as she saw all three evolving. The most striking

features are the long snout and the pipe-like, toothless mouth, suited for a dainty diet of very minute organisms; the laterally compressed body, bucklered like an armoured horse; the beautiful median dorsal fin, vibrating with great rapidity, and helping, along with the small pectorals, to effect leisurely locomotion; and the four-cornered prehensile tail, movable dorso-ventrally, whereas that of ordinary fishes moves only from side to side. With few exceptions, such as the skate, fishes swim by the lateral strokes of the posterior part of their body, popularly and roughly called the tail. But in the sea-horse the tail has become a prehensile organ, by which the fish moors itself to floating seaweed or the like. Much of the locomotion is, so to speak, passive, the sea-horses being drifted about with the sea-ware; for short distances they utilize their quivering fins, especially the dorsal one; with their tails they clamber about among the fronds, like far-off anticipations of monkeys. Their poses as they play hide-and-seek among the seaweed are indescribably quaint. When they are swimming gently the cuirassed body sinks more and more from the vertical, as if they were falling forward in the water, and then they pull themselves straight up again, only to repeat the performance. When they are resting, often with the tails of several intertwined, they are more huddled up, each a little like a broken-backed capital S. Some naturalists have heard the sea-horses make a faint clicking sound, probably coming from the swim-bladder, which seems to be an important hydrostatic organ in these queer fishes. A little olive-brown sea-horse (*Hippocampus antiquorum*, see Fig. 172), with bluish-white spots and lines on the sides and tail, is occasionally found on British coasts. It is common in the Mediterranean, and a joy in many aquaria. But sea-horses are to be thought of as specially adapted to floating banks of seaweed—a habitat which has a quite characteristic fauna of its own. Among the weed the quaint creature is elusive, and this is particularly true of an Australian type, *Phyllopteryx eques*, which is festooned with frond-like ribbons, like an over-decorated horse. It is very difficult to tell where the seaweed ends and the tasselled fish begins. Of the frond-like ribbons some of the commoner species of sea-horses show slight hints.

The eyes of chamaeleons have a peculiar way of moving independently. The reptile gets its right eye focused on an insect and then its left; when the two are properly adjusted, out comes the long, knobbed, sticky tongue, and the insect is caught. It is interesting to find in the common *Hippocampus*—a fish, not a reptile—the same independent movement of the two eyes. 'One eye,' Dr. Gill remarks, 'may roll toward you, while the other may be passive or look backward or in an opposite direction.' That this peculiarity should occur in such widely separated types is an illustration of **convergence** or **parallel**

evolution; it may have something to do with the laterally compressed head in both sea-horse and chamaeleon, for this gives the eyes an extremely lateral position. Yet it seems curious that the two widely separated types should also agree in having prehensile tails!

So quaint a creature as the sea-horse could not fail to attract the attention of the old naturalists, and they have treated it with their wonted generosity. In spite of its small size, it becomes a 'sea-dragon' or 'zidrach.' 'The most strange fish,' says John Josselyn (quoted by Professor C. R. Eastman), 'is a small one, so like the picture of Saint George his Dragon, as possible can be, except his legges and wings.' '*Caput habet ut equus*,' says another, '*sed forma minori. Corpus autem ex omni parte draconi simillimum est; totumque diversimente coloratum*.' 'Out of water it can do nothing, but dies instantaneously.' And its ashes, of course, duly commingled with oil of sweet marjoram, will cure many diseases.

But what in the fanciful descriptions of the ancients is there to compare with the scientific fact of the sea-horse's paternal care! On the under-surface of the male, nearly opposite the dorsal fin, there is a capacious pocket opening forwards. At the breeding season the lining of this pocket becomes thicker and more rich in blood-vessels. It is being prepared as a cradle for the reception and development of the eggs. The female *Hippocampus*, burdened with eggs, presses her body against the opening into her mate's pouch, and an egg slips in. She retreats and advances again, and another transfer is effected. Such, at any rate, is the gist of the account given by Dr. Fanzago of what he observed in an aquarium at Naples, but we would gladly have more details in regard to so interesting a habit. It is rather interesting to notice that in the foliaceous sea-horse (*Phyllopteryx*) there is no pocket for the eggs; they are simply embedded in the soft skin groove underneath the tail. Perhaps this represents a preliminary step towards the evolution of the marsupial habit. In our pipe-fishes (*Syngnathidae*), where the elongated body is all in one line, the brood-pouch is well developed in the males. In these forms it is said that the female lays the eggs, and that the male takes them and puts them into his pocket. In the distantly related *Solenostoma* the pelvic fins of the female form the pouch. There are, among fishes, comparatively few illustrations of parental care, but those that occur show considerable originality. In some cases where there are few eggs, and the risks of their being devoured are great, the male shelters them in his mouth, and this involves a prolonged fasting. We may recall that in the fish called *Kurtus* (p. 798) the newly laid eggs become entangled by filaments into a double bunch, which the male somehow or other fixes under a bony hook on the top of his head, and in this quaint way he bears about his family in safety until the eggs hatch and the

young ones swim away. In the foot-long *Aspredo* of the Guianas the skin of the under-parts of the female becomes spongy, and to this the eggs, after being laid, are attached in a single layer, each one acquiring a tiny vascular stalk. But if there is parental care among fishes it is usually paternal, not maternal.

What is the theoretical interpretation of these facts? Most fishes are exceedingly prolific; many have hundreds of thousands of eggs; and some, like cod and conger-eel, have their millions. There is enormous infantile mortality, but the birth-rate is so high that the continuance of the race is secure. With progeny so abundant, there is no need for parental care; variations in the direction of increased reproductivity would not, in ordinary cases, have any survival value. Moreover, the majority of fishes are not highly individuated as regards brains. They keep to that crude but effective solution of the problem of survival which is to be found in prolific spawning. The success of our fisheries shows how well that solution works.

But if, in the course of evolution, a type of fish reached a constitutional state in which its reproductivity was greatly reduced—in which there were, perhaps, only a few large eggs of slow development, or in which the conditions of life in the habitat were very severe, and the Mirza bridge was more than usually difficult to cross—*then* a contemporary variation in the direction of some form of parental care, or in some other mode of securing the safety of the young, would certainly pay. If it did not arise, the race would disappear. Those rare types that have survived in the difficult conditions of life already alluded to are such as have varied more or less simultaneously in the two directions of economized reproductivity and increased parental care. No one is at present wise enough to say whether there may not have been some deep correlation of the two kinds of variations—physical and gonadic—in a creature with so much individuality as a sea-horse, or to tell us whether the variation in the brain would be more likely to precede or to follow the variation in the reproductive organs. If the gonadic variation emerged first, its occurrence would give survival value to cerebral variations in the direction of parental care. If a cerebral or psychical variation in the philoprogenitive or parental direction came first, its emergence would give survival possibilities to variations in the line of economized reproductivity. In no case would success be secured unless the two kinds of variations evolved hand in hand. We see in *Hippocampus* (which, by the way, is said to mean 'horse sea-monster' a pioneer in the movement to get away from the spawning solution to the parental care solution, in which there is more promise. To the question, why the parental care, as illustrated by a few striking cases among fishes, should be, at this level, *paternal* oftener than maternal, the only suggestion we can make is that the

female tends to be much more exhausted by her parenthood than the male is; occasionally, indeed, she dies after spawning.

Social Animals

SENSE OF KINSHIP.—It is said that when many people of different races, nationalities, and classes are thrown together, say by some disaster, like a shipwreck on an island, they tend to consort together in groups of similars. All the English public-school boys come together, and all the Orientals. Let us suppose this is true, how is it to be explained?

To some extent, no doubt, there are rather superficial reasons for the herding together. We are most comfortable, and our self-esteem is best assured, when we are with those who are familiar with our accent and our catchwords, who share our conventions and prejudices. We cannot be at home with a man who flaunts a made-up tie! But when we have allowed for all those features which produce what may be *metaphorically* called 'the smell of the pack'—different for each pack—we find reason to suppose that there are deeper samenesses which draw people together and exclude others from the company. Those of the same kindred draw together.

One reason for looking below the superficial reasons to deeper ones is that animals often show *a sense of kinship* that depends on bodily sameness rather than on anything like the conventions and prejudices that we are familiar with in mankind. It is often *literally* 'the smell of the pack' that serves as the basis of animal freemasonry. Thus ants and bees, which admit without question one of their own family or community, will at once resent its appearance if it has been sprinkled with the odour of another species. Conversely, a stranger-insect may enter the nest or the hive unchallenged if it has been anointed with the extract of the rightful tenants. There is no warrant for supposing that the ants or bees argue from the familiar or unfamiliar odours to the fact of friend or foe; what happens is probably at a much lower reflex level. But the scent serves none the less as a signal of kinship. We believe there is warrant for assuming that many animals have a sense of organic kinship.

We took two eggs of the black-headed gull from the nest and hatched them in the laboratory incubator. The young birds, to which we acted as foster-parents, were eventually placed on the lawn and brought up there very successfully without any knowledge of their kindred. There were two disabled herring-gulls on the same lawn, but the young black-headed gulls, belonging to a very different species, paid them no attention. As the summer months passed, our black-headed youngsters became excited when members of the same species

passed overhead; and when they were themselves able to fly, they joined their comrades in migration. No doubt, to make sure, we should have made scores of similar experiments, but the suggestion of an organic kin-sympathy was strong.

ADVANTAGES OF SOCIALITY.—Some animals are solitary by nature and habit, while others are social and fond of company. If we trace the social disposition back to an organic kin-sympathy, we must also show how it would be fostered in the course of ages, and would grow from more to more. Given a native kin-sympathy, variations or new departures in the direction of sociability would take grip and increase *if* they were advantageous. What are the advantages that made sociality in certain cases profitable? The answer is manifold:

(1) Union is strength; there is safety in combination.

(2) Co-operation increases efficiency and economy of effort.

(3) In animal societies there is a chance of permanent products, e.g. a shelter.

(4) A society favours division of labour.

(5) A society favours the advance of both intelligent and instinctive behaviour.

(6) Social life fosters kindly feelings and other-regarding endeavours.

(7) Social life allows of variations which would be apt to be nipped in the bud in solitary life; it is a shield and shelter—sometimes too much so.

GRADES OF SOCIAL LIFE AMONG ANIMALS.—In some kinds of animals, e.g. solitary hunters like the otter, anything like communal activity would be out of the question. Anglers do not fish in 'elevens.' Among spiders there are only two or three social species. From among the grades of sociality we select the following:

(*a*) Large numbers of the same kind of animal may live together gregariously, but with little more sociality than mutual tolerance, as in a rabbit warren, or on a sea cliff crowded with nesting guillemots.

(*b*) There may be a herd or flock with some unity of action, e.g. in following a leader, in keeping together, in protecting the young. This is seen in herds of wild horses, cattle, and elephants.

(*c*) There may be unmistakable, yet relatively simple, combinations in a united effort, as when wolves form a hunting pack in winter, or when sand-martins combine against a hostile intruder.

(*d*) Large families or combinations of large families occur among ants and other social insects, and there may be much division of labour and communal organization, mainly on an instinctive basis. In some cases, e.g. termites, the society lasts for years; in other cases, e.g. wasps, it comes to an end as such when the summer is over.

(*e*) The highest forms of animal society are to be found among rooks, cranes, beavers, and monkeys, where there seems to be intelligent as well as instinctive behaviour.

CHAPTER II

HAUNTS OF LIFE

Where did the first organisms live?—What were the first organisms like?—Great haunts of life—Haunts in general—The deep sea—The waters under the earth—' The sea's abundant progeny '—Pond-life—Arctic survival—The tundra—The tropical forest—The underworld—The biology of dust—Fauna of a moor—Drama of the hedgerow—Wonders of the roadside.

THE only organisms or living creatures that we know anything about are those that are composed of protoplasm; therefore we need not speculate about any other kind of life, which we cannot even imagine.

Since there cannot be protoplasm except where there is water in liquid form, it is only between certain narrow limits of relatively low temperature that organisms can live, and the earth is the only place which we definitely know to be a home of life. Of a few other ' heavenly bodies ' like Venus and Mars, it is said by some good authorities that they may *possibly* be the homes of living creatures of the same general nature as those we know, but this is only a *possibility*, as far as secure knowledge goes. As to the possibility of there being on other heavenly bodies *other forms of integration quite different from organisms*, every man's opinion is as good as his neighbour's. There is little use in speculating about creatures that we cannot picture or conceive of. So far as we know, our earth is the only home of life in the biological sense.

How did living creatures begin to be upon the earth after it cooled to within the limits of temperature that would allow of the presence of any living creatures that we can imagine? This is a question that we cannot answer with any certainty, though there are various facts that favour the suggestion that the first organisms on the earth evolved in a natural way from non-living materials. Of these facts the most striking are the achievements of the synthetic chemists in building up simple components into very complex substances, such as carbohydrates and amino-acids. Some of the last-named, e.g. glycine, leucine, and tyrosine, go to form **proteins,** which are always constituents of protoplasm. Amino-acids have been called ' the building-stones of life.' But we do not know what processes in Nature would take the place of the highly intelligent synthetic chemist. If we accept this suggestion, that **spontaneous generation** occurred long ago, though we cannot find any experimental evidence of it occurring to-day, we must clearly understand that it remains no more than a working hypothesis.

Another suggestion is that germs of life came to the earth from elsewhere, but we know nothing about the 'elsewhere.' Moreover, the suggestion of arrival of simple organisms on a meteorite or the like only shifts the responsibility of the problem off the shoulders of this planet, quite apart from the inherent unlikeliness of such a journey.

Another suggestion, which does not pretend to be in any way a *scientific* answer, is that living creatures arose upon the earth in some mysterious way beyond all scientific analysis. To say that the first organisms on the earth arose by divine agency, may be true or a truism, but it is not the kind of answer that Science seeks. It is a transcendental, not an empirical answer.

WHERE DID THE FIRST ORGANISMS LIVE?—This is another difficult question to which only a hesitating answer should be given. Were living creatures cradled in the Open Sea, or in the Shore Area, or in the fresh water? It cannot have been on the floor of the *Deep Sea* that the first organisms were at home, for it is enough to note that the absence of light implies the absence of green plants, which furnish the basal food-supply for animals. It cannot have been on *Dry Land*, for the conditions of terrestrial life are hazardous as compared with those in water, as may be illustrated by the risks of drought and by the greater difficulty of breathing dry air, and of cradling the early stages of the individual development. Moreover, apart from some single-celled animals, such as certain *Amoebae* and *Infusoria*, none of the simple animals, including the sponges and *Coelentera*, can live out of the water for more than a short time. The same kind of argument may be used against regarding the *fresh waters* as the original home, for, in the two lowest classes or groups of many-celled animals (*Metazoa*), all the sponges are marine except the single family of freshwater sponges, the *Spongillidae*; and all the stinging animals or *Coelentera* are marine except half a dozen or so, such as the freshwater *Hydra* and the freshwater Medusoids. Now when we find a class with half a dozen or so different representatives in fresh water and many hundreds in the sea, it is presumably safe to conclude that the sea was the first home, and that the fresh waters were secondarily colonized.

The question is thus reduced to this: Did living creatures begin in the Open Sea or in the Shore Area? In favour of the Open Sea may be noted its spaciousness, the relative absence of rocks against which organisms might be shattered, the present-day exposure of countless millions of simple floating plants to the sunlight, the comparative sameness of the conditions throughout the year. Against the idea of the Shore Area as the original home may be noted the rough-and-tumble conditions in shallow water, the frequency of physical change, the insecurity of the food-supply, the severity of

the struggle for existence. But these cannot be regarded as *fatal* objections to the theory that the first living creatures appeared in some sheltered corner of the primeval shore where there was sunshine without storms, very stimulating changefulness, opportunities for concentration, and chances of catching ammonium nitrite or the like brought down by thunder-showers. Another possibility for which much may be said is that the primitive organisms *began* in the Open Sea, and that many of them passed thence to the Shore Area, which is well suited to serve as a school of life. Perhaps many of the higher classes of animals served a racial apprenticeship in the shallow water of the seaweed area near shore.

WHAT WERE THE FIRST ORGANISMS LIKE?—It is likely that the first organisms were very minute, gently swimming single cells, of very simple structure, of very short life, and able to utilize some of the rays of sunlight as a source of energy, which they changed into the potential energy of carbon-compounds. They probably consisted of a **nucleus** surrounded by an envelope of **protoplasm**, and this was probably drawn out into a single motor lash or **flagellum.** It may be that they fed and grew during their first day and divided into two in the early watches of the night, their individual existence then ceasing; but while we may think of them as very short-lived, we may also think of them as immortal, since the individual A is continued into the offspring B and C to which it gives rise by division. Thus some biologists follow Weismann in speaking of the bodily **immortality of the unicellulars,** meaning that even now these simple creatures do not die a *natural* death. As we have already mentioned in speaking of the *Protozoa*, they may die a *violent* death, e.g. by being swallowed, or by being over-heated or over-chilled; but that is very different from dying a *natural* death.

In shallow areas of the primeval sea some of the original organisms found anchorage, within reach of the light, and grew into threads, platelets, globes, fronds, and encrustations—**the first fixed plants.** From some of these, in the course of ages, there evolved the **seaweed vegetation,** which we see exposed in great profusion and diversity when the tide goes out. It may be that some of these seaweeds, most of which are still at a low level of structural complexity, gave rise to the pioneer land plants. Taking a companion so as to lessen risks, we should go cautiously down to the lowest zone that we can reach, and look round at the array of seaweeds, mostly brown and red, for there is no doubt that there was for long ages no vegetation higher than these.

It was among the primitive seaweeds in all probability that there arose organisms with a quite different way of living. They obtained their food from fragments broken off from the seaweeds by the waves

—they were the first **predatory organisms**, the first animals, single-celled creatures a little like the amoebae and Flagellate Infusorians of to-day. Using a symbol, the genealogical tree, we may say that it began to fork like a letter V or Y, plants and animals diverging in different directions from a common ancestral stock. The primeval organisms, at the base of the V or Y, may have required some time before they took decisive steps to right or left, in the direction of plants or in the direction of animals; and while they are hypothetical, it must be kept in mind that there are many somewhat undecided organisms in the waters to-day. They are often called **Protists.**

GREAT HAUNTS OF LIFE.—There are six great haunts of animals: the Open Sea (**Pelagic**), the Shore Area (**Littoral**), the Deep Sea (**Abyssal**), the Fresh Waters, the Dry Land (**Terrestrial**), and the Air (**Aërial**).

On the floor of the Deep Sea there are no plants save some resting-stages of down-sunk algae, so this cannot be included among the haunts of plants. But the other five hold good for plants as well as animals. We may even include the aërial haunt, for many 'perched plants' or **Epiphytes** live high above the ground on the shoulders of trees, and many fruits are wind-borne.

The Open Sea is marked by its abundance of room and food, by its uniformity and relative safety. The Shore Area is the seaweed-growing, well-lighted, shallow-water tract around the coasts; it is marked by its vicissitudes, its crowding, its keen struggle for existence, its numerous shifts for a living. The Deep Sea or Abyssal Area, though hidden from view, covers more than half of the earth's surface; it has an abundant and diverse fauna, probably derived for the most part from the shore fauna; its food-supply is ultimately due to the rain of small organisms from the surface and near the surface. There are no plants at home in the abysses.

The Fresh Waters include lakes, ponds, rivers, marshes, and so on, and there is a rich flora as well as fauna. The tenants of a lake are usually very different from those of a swift stream, but there is in most cases a marked general sameness between the tenants of lakes even when these are widely separated. This is partly due to the similar *origin* of many lacustrine animals, whether as migrants from the sea, or crowded off the dry land, or through seas becoming lakes, for the same kind of animal would naturally survive the similar risks which would be in most cases involved in the change of habitat. A true lake is distinguished from a huge pond by having a deep-water area, as well as the shallow littoral area and the wide expanse of open waters.

As to the Dry Land, it is useful and graphic to think of its successive **colonizations** from the waters, salt or fresh. The most important of

these were the following: (1) the worm colonization, begun by pioneers like *Turbellaria* (q.v.), which eventually led to earthworms and the making of soil; (2) the air-breathing Arthropod invasions which eventually led to insects and the important linkages between flowering plants and their pollinating visitors; and (3) the Amphibian colonization, in late Devonian Ages, which led on to Reptiles, and thence to the higher life of Birds and Mammals. It is essential to think of the pioneer terrestrial plants as preparing the way for the terrestrial animals.

The Aërial haunt was first entered by insects, secondly by the extinct flying reptiles called Pterodactyls or Pterosaurs, thirdly by the flying birds, and fourthly by the bats, each solution of the problem of flight being on a line of its own.

Besides the six great haunts of animal life, we must think of *minor haunts*, such as caves, trees, mountains, the underground world, and the interior of other organisms. It is also evident that we must subdivide the aquatic and terrestrial haunts. Thus we distinguish pond plants, river plants, marsh plants, shore plants, desert plants, and so on. Every niche of opportunity is occupied.

In what follows of this section we give a variety of illustrations of the haunts of life and the ways in which organisms use them.

Haunts in General

One of the great facts of Organic Evolution has been the peopling of land and sea—*the discovery of new haunts*. The spur to exploration has been the struggle for existence, in which we must include the whole **urge for more**—more food, more room, more love, more ease, but also in higher forms something of the spirit of adventure. The higher animals at least often send out tendrils of inquisitiveness.

This search for new haunts continues to-day, and it is interesting to study the peopling of a new water-way (like the Kiel Canal), or a new asylum (like a mine), or a new area of exploitation (like the houses of a town). It has been possible to follow the complete history of an island newly made in a river, and its history is a miniature of the peopling that has proceeded for ages over earth and sea.

It is particularly interesting to notice new habitats, especially when they are associated with some change of habit, but we must be careful to avoid the common error of looking at the newness of the haunt from our human point of view. A bird nests in a lamp fixed over the platform of a small railway station in the country—a lamp that is never lighted during the summer months. This site appears very strange to us, and it is in some measure strange; but we mistakenly exaggerate its strangeness by forgetting that the site is not a railway

lamp to the bird. It is merely a safe, dry shelf, a little difficult to enter, but otherwise convenient enough. Similarly when a bird nests inside the empty arm of a scarecrow's jacket, it is not in the least aware of the quaintness of its nesting-place. Again, we have seen freshwater snails browsing placidly among the weed-covered stones a few feet above the brink of the Falls of Niagara, and a spider may spin its web across the cavity of the pitcher-plant (*Nepenthes*).

In a new haunt an organism may undergo some **modification,** by which term is meant some change directly due to a peculiarity or novelty in the environmental, functional, and nutritional influences—a change that transcends the limits of organic elasticity and persists even after the peculiar or novel conditions have ceased to operate. These modifications are badly called **acquired characters,** a term that stresses the fact that they are acquired during the individual lifetime and were not inborn. We have no certain knowledge that they are continued *hereditarily* in the next generation, but they are likely to reappear if there is a persistence of the peculiarities that first induced them. Our present point is that not a few of the constant characteristics of plants and animals may turn out to be modifications, hammered on each successive generation by the conditions of the same sort of haunt. It is very desirable that many experiments should be made in the way of shifting organisms to haunts markedly different from those in which we have always known them. In some cases the characters under observation are not affected by the change, which goes to show that they are *not* modifications wrapped up with a particular haunt. But more experiments are urgently needed.

As we have noticed, and as every one can see for himself, organisms tend to *vary*. That is to say, novelties crop up among their offspring—novelties of all sorts, in size, shape, colour, strength, pace, wits, and so on. Later on, when we discuss **Evolution,** we shall say a little about the origin of these inborn **variations,** which differ from modifications inasmuch as they emerge from within and are not impressed from without. They are expressions, not dints—'endogenous,' to use the technical term, not 'exogenous.' Many variations pass readily, as part of the inheritance, to the next generation; and they are to be regarded as *the raw material of possible evolution.*

Now one of the ways in which variations may arise is through the saturating influence of peculiarities in the haunt or environment. Peculiarities like those of climate, for instance, may penetrate through the body and provoke the *germinal material* to change. It is not that these peculiarities in this case produce modifications or dints; it is that they induce new permutations and combinations in the changeful living matter of the germ-cells—the ova and spermatozoa—thus affecting the offspring into which these may develop.

When variations arise in a haunt that shows some form of **isolation**, they are the more likely, if not disadvantageous, to become firmly established; for the chances of intercrossing with different variants from elsewhere are lessened. Thus many islands have species peculiar to them, like the St. Kilda wren, the Orkney vole, the Foula mouse, and the different giant tortoises on different islands of the Galapagos Archipelago. The sides of a deep valley may form an impassable barrier, as with the beautiful land-snails in Hawaii; and the isolation is sometimes very subtle, as when different groups of gopher or pouched mouse in the Californian desert region are separated by broad arid tracts which are too extensive to be crossed without starvation. We see, then, that some form of isolation may add to the evolutionary interest of a distinctive haunt.

The tenants of a well-defined haunt are often marked by hereditary peculiarities which are suited to the particular conditions of life; and these **adaptations**, as they are called, are often exhibited by fellow-tenants that are not related to one another. In short, similar adaptations may have been wrought out in the course of time in different types *by the sifting or selection of similar variations*. Desert plants are often adapted to the difficult conditions of their life by structural arrangements which enable them to store water in the rainy season, or to collect it from a wide area by their long roots, or to lessen the loss of it from the leaves, which are often reduced to spines; and similar desert adaptations often arise in unrelated types, as may be seen in cactuses and spurges. Similarly, a worm-like shape in animals is well adapted for burrowing in the ground, and it may be seen in subterranean amphibians, lizards, and snakes which are not nearly related (see CONVERGENCE). We see, then, that the study of the various haunts must lead us to inquire into the adaptations of the plants and animals that live there.

An interesting adaptation to the conditions of life in particular haunts is in the rate of life or **metabolism**. Thus the vital processes in *Gammarus pulex*, a common little crustacean in fresh water, are much more rapid than those of nearly related species, e.g. *Gammarus locusta*, whose haunt is the seashore. The same difference in rate of metabolism may be seen in contrasting a larval may-fly that lives in rapid streams with another species that lives in ponds. Thus we may say that in different haunts there may be a difference in the physiological gearing of nearly related species; and though this has only been proved (by Professor Munro Fox and others) in a few cases, we may safely predict that it will be discovered in many.

Widely separated haunts, e.g. lakes, often show very similar tenants. Why is this? (1.) It may be because a once widespread type has been exterminated by natural changes over the area between the haunts in

question, for the single reason that the conditions of life became in some way very unsuitable. Thus a widespread cutting down of forests may leave similar survivors in woods which the axe or the fire spared. (2) Or it may be that similar variations cropped up in different isolated centres and survived because they suited the similar conditions of life. Thus similar cactuses may be found in widely separated desert areas. (3) It may be that the tenants are carried by birds and other living transporting agents from one haunt to another, but only to those which the transporters like. Thus similar insects are often found on a similar kind of tree standing alone in the centre of widely separated fields. (4) But we must not forget that animals with some similarity of constitution, e.g. weak eyes, may actively seek out similar haunts where they are most comfortable.

A goldfish kept in a dark room, but otherwise in wholesome conditions, has been known to become quite blind in three years, losing the rods and cones of its retina. We do not know, however, that its offspring reared in a lighted aquarium would show any prejudicial effect of their parent's acquired blindness. The experiment has not been tried. But our uncertainty as to the **transmissibility** of modifications or acquired characters leads us to be very cautious in concluding that the blind fishes, crustaceans, insects, and other animals found in caves have become blind, in the course of generations, as the direct result of the surrounding darkness. Perhaps the blindness arose in the cave as a **germinal variation**, and while those of the species that remained with good sight found their way out, the blind variants remained cavernicolous, and were not much the worse, since eyes are probably a source of danger to animals living in very complete darkness.

But we wish to suggest another of the possibilities of interpretation, one which lays emphasis on the animal as a personal agent. It may be that an animal which has varied constitutionally (i.e. germinally) in the direction of weak eyes may seek out a haunt where it is least uncomfortable. Similarly a lichen-like spider may make a habit of lurking on lichen-covered bark of the same colour. Animals are not passive pawns, they play their own game of evolution. *They play their hereditary cards.*

Mr. Elliot Howard has shown that among birds, e.g. warblers and buntings, the haunt of the pair is carefully chosen by the male and approved of afterwards by the female, and comes to be of much importance in the conjugal and family life. It may be a particular tree or bush or cairn; it is held as a 'preserve' and often fought for; it may become a psychological centre of great suggestive and activating value to both sexes. In its mental functioning it may approach the rôle of a 'home' in mankind. It is technically called the 'territory.'

Professor Charles Elton has recently described the occurrence of 'territory' in the wood-ant (*Formica rufa*). 'Each nest had a distinct territory, containing certain trees and shrubs on which lived almost pure cultures of aphids tended by the ants for their secretions, and forming the basis of trackway systems from the nests. There was no communication between the trackways of neighbouring nests, nor normally any hostility between ants of different nests, except for occasional destructive raids.'

This 'territory' is obviously rather different from a haunt in the ordinary sense, but it is a cognate idea and sounds a very interesting note.

We must not think of haunts in any hard-and-fast way, for the same organism may frequent different haunts, and a haunt may change greatly in the course of the year (see SEASONS). In many cases an animal has two haunts in the course of its life, changing from one to the other as it develops. Thus many distinctively shore animals, such as crabs and starfishes, are at home in the Open Sea during their delicate youth. Many very thoroughly aërial insects, such as may-flies and dragon-flies, spend their early days—even years—in fresh water. Every one knows that frogs and toads are thoroughly aquatic during their tadpole phases. The robber-crab (*Birgus latro*, see Fig. 93) of Christmas Island and elsewhere, that climbs coco trees for the nuts, spends its early life in the shallows near the shore of the island.

The Deep Sea

This haunt is an unseen world, yet we know a great deal about it and the animals that live there. From a ship we can throw a stone into it, but a visit is impossible on account of the enormous pressure—in many places several tons on the square inch. By the Deep Sea is always meant the floor of the ocean at great depths and the zones of water near the floor. Not much is known about the 'mid-waters' between the illumined surface zones and the dark abysses. The floor of the Deep Sea occupies more than a third of the earth's surface, so it is not a small haunt of life that we are thinking about.

If the Deep Sea cannot be visited, how do we know so much about it? Because explorers from all nations have reached down with the long arm of the dredge from all sorts of places in all the seven seas, and have brought up abyssal animals from depths sometimes of several miles. By means of bottles that can be opened and shut at the great depths, samples of the water have been obtained, and there are other devices for obtaining samples of the mud and similar deposits, usually called Deep-Sea ooze. By means of a little metal messenger sent whirring down a wire it is possible to expose thermometers at

particular depths, and what they register can be fixed so that it does not change on the way up. Something has been known about the Deep Sea for over a hundred years, but the most important exploring expedition was that of the *Challenger*, 1873–6: important in itself and important in prompting others. With a staff of naturalists aboard, including Sir Wyville Thomson, Sir John Murray, and Professor Moseley, the *Challenger* cruised over 68,900 nautical miles and raised treasures of life from over three hundred stations. The spoils required fifty huge volumes for their description. The *Challenger* Expedition might well be called a 'Columbus voyage,' for it practically discovered a new world—the world of the Deep Sea.

In trying to picture this strange haunt of life we should think first of its great depth. The average depth of the ocean is about two and a half miles, and as vast tracts are shallow, there must be others that are very deep. In some places Mount Everest would be quite engulfed with 2,600 feet to spare. What is called the Challenger Deep goes down for nearly six miles, and a depth of slightly over six miles has been recorded.

Now the depth involves enormous pressure, which at 2,500 fathoms amounts to two and a half tons on the square inch, a much greater pressure than that which drives the piston of an ordinary railway engine. If a beam of wood is lowered with weights, it comes up so compacted that it will not float. If a ship's hawser is lowered it is squeezed into the thickness of one's wrist. A great slab of whale's flesh is pressed into pemmican. Yet from these abysses we dredge delicate animals whose skeleton a child's fingers could crush, and some of the most daintily built animals in the world come from beneath miles of sea. The explanation is that the porous bodies are permeated with water through and through, so that the pressure is not felt. If a closed glass vessel is lowered it is soon shattered into powder; but an open glass vessel is of course unaffected, the pressure inside and out being the same. So it is with the Deep-Sea animals.

As the sun's heat is lost at about 150 fathoms, the Deep Sea is very cold, varying a little on each side of 32° F.,the freezing-point of fresh water. There is very slight change throughout the year. Eternal winter reigns. It has been shown that cold water, rich in oxygen, is always sinking down from the Poles, especially from the Antarctic northwards.

As the rays of light are practically lost at 250 fathoms, and as the most sensitive photographic plate is unaffected when automatically exposed below 900 fathoms, which is rather over a mile, the abysses must be very dark. If it were not for the fitful gleams of some luminescent animals we might think of the Deep Sea as swathed in eternal night.

We must add to our physical picture of the Deep Sea that it is

very calm, without any rapid currents, and that in many places the floor is thickly covered with powdery ooze. There is unbroken silence, and there is no scenery except a few ridges and gullies, and here and there a volcanic cone—a strange, dark, cold, calm, silent, monotonous world.

As to the Deep-Sea animals, there must be much that is interesting. In the first place, though there are some abyssal deserts with very few inhabitants, and though there are more animals at moderate depths than in the great 'deeps,' the big fact is that there is no depth limit to the distribution of life. Very important is the absence of plants, apart from the resting stages of some simple seaweeds. The reason is, of course, the absence of light, and the consequence is that animals must all be carnivorous. But as they cannot all be eating one another, we look for an extraneous food-supply, and find it in the slow, ceaseless rain of infinitesimally small creatures sinking down through miles of water like snowflakes on a quiet winter day. No doubt some larger animals, like sharks and whales, contribute to the thinly spread abyssal table. As there seem to be no bacteria in the Deep Sea, there can be no rottenness, and the compressed carcass of a whale is simply nibbled away by thousands of small crustaceans.

It is interesting to think of Sir John Murray trawling with a fifty-foot spread of otter trawl at a depth of 2,820 fathoms, which is over three miles. What kind of animals did he capture? The answer is that most of the great classes up to fishes, barring of course the air-breathing insects, are well represented in the Deep Sea—sponges, corals, worms, starfishes, sea-urchins, crustaceans, sea-spiders, all sorts of molluscs, and then the queerest of queer fishes. It is a very representative fauna that peoples the inhospitable world of the Deep Sea. Thousands of different kinds have been described; some have been seen only once.

One of the fascinations of Natural History is the discovery of fitnesses, for every creature is suited to its habits and habitat. What are the outstanding adaptations of Deep-Sea animals? Many of them, like the sea-lilies and sea-pens, are raised on long stalks out of the soft ooze. Others, like many of the crabs and sea-spiders, have almost incredibly long legs, out of all proportion to their bodies. They are among the lankiest creatures in existence, and are able to stalk about delicately as if on stilts. This probably saves them from floundering deeply in the ooze, which has sometimes the consistence of butter on a hot day.

The Japanese flinty sponge called *Euplectella*, or Venus's flower basket, rises like a fairy palace from the floor of the Deep Sea, and it is a good example of the delicacy of build that we have already mentioned. The body is so permeable that the enormous pressure of the

miles of water is not felt. In some of the fishes even the bones are so delicately built that one can run a needle into them without breaking the point. When a hungry Deep-Sea fish rises quickly in pursuit of a Deep-Sea prawn, it may get into a zone of water where the pressure is less than inside the body, and, if it has not time to adjust things, it may be forced upwards and upwards to the surface, where it explodes! The internal organs may be forced out of the mouth, and even the scales may be driven off. The Deep Sea is the only place in the world where creatures can tumble upwards, but it does not happen often.

In a world of darkness, eyes are not likely to be of much use, and we are not surprised to find an extraordinary development of touch-organs, such as antennae and other kinds of feelers. One of the abyssal fishes dredged off the west coast of Ireland has a tactile barbule many times the length of the body, and some of the prawn-like crustaceans have antennae three or four times their length. These touch-organs must be very useful for feeling the way in the dark abysses, being doubtless used as a blind man uses his staff. Some of the Deep-Sea animals are perhaps the touchiest creatures in the world, though bats will run them close.

This raises a question in regard to the eyes of fishes. In some cases we know of shore fishes with average eyes which have relatives living at 300-600 fathoms, and these have big eyes—in adaptation, we naturally say, to the scanty light. And there are other relatives that live at great depths of over 1,000 fathoms, and they have very small eyes. Which is as it should be, for there is no light at 1,000 fathoms, and a useless eye is not only a needless expense, but may be a weak spot if it is injured in a collision. But the difficulty is that among the abyssal fishes, many of which have dwindling eyes, there are some with large goggle-eyes. If we say that small eyes are what we should expect in an eternal night, what are we to say of eyes in the same surroundings that are larger than usual? In some cases the big-eyed abyssal fishes may be relatively new-comers, but perhaps a slightly more satisfactory answer is that the big-eyed species take advantage of the gleams of luminescent animals.

The luminescence or, as it is badly called, phosphorescence of many Deep-Sea animals has been studied in a dark room on board ship when the light-producers survived the upward journey. It is a cold light without any heat-rays, and it seems usually to be produced by a rapid oxidation accompanying a fermentation. A substance called a luciferase ferments another substance called a luciferin, and a bright light results. Sometimes the light is produced inside an eye-like organ; sometimes a luminous secretion is exuded into the water. It probably has different uses in different Deep-Sea animals—a lantern to some, a lure to others, here a love-signal and there a warning, but we must keep in

mind the possibility that it often has no use at all, but is simply a by-product of the chemical and physical routine of the body. We know that a fire-fly or glow-worm uses its light as a signal in courtship, but we can only guess, as yet, at the use of luminescence to a brittle-star or a sea-pen living in the abysses.

Another puzzle is the frequency of colour among animals living in the world of darkness. Thus there are many brilliantly red crustaceans, and there are also blues and yellows. Perhaps we press too hard in trying to discover a use for everything; perhaps the bright colouring of many Deep-Sea animals is simply a by-play of the chemical routine and the minute structure of the tissues. In the same way it is difficult to be sure that there is any use in the brilliant autumn colouring of the withering leaves, which we might almost call the flowers of the forest.

A different kind of puzzle is raised by the question: Whence did the Deep-Sea animals come? The answer must be that most of them are migrants from the illumined seaweed-growing shallow waters round the coasts—migrants that have followed the down-drifting food along the slopes which lead to the abysses. There are few very ancient types in the Deep Sea, and it is unlikely that there was much colonization of the abysses before the Cretaceous period. The colonizing of the inhospitable abysses is one of the many instances of the urge of life to overflow into every vacant corner, and it is a noteworthy fact that we find abundant beauty, fitness, and vigour in the strange, cold, dark, silent, plantless world of the Deep Sea, across which there stretch the cables by which man has annihilated distance.

THE SARGASSO SEA.—The so-called 'Sargasso Sea' is the centre of a great 'Gulf Stream' whirl in the North Atlantic, and its almost resting waters are thick with seaweed. Most of this weed seems to be torn from the shores of Florida and the like, and, as a matter of fact, there are several 'Sargasso Seas' and several 'Sargasso weeds.' Some species of the latter are actually at home in the Open Sea, and have long branched stems furnished with gas-bladders that act as floats and keep the plant within the light. The particular point in making a thorough exploration of the Sargasso Sea is that it represents an 'association.' There are numerous animals among the weed that have become specially adapted to this vast floating meadow, and are not found anywhere else. Some of them, instead of being translucent, blue, or greyish, like many pelagic animals, are clothed in reds, browns, and dull greens like the weed amid which they hide.

The Waters under the Earth

One of the characteristics of living creatures is their insistence on peopling not only the great expanses of land and sea, but every hole

and corner of them both. If Nature abhors a vacuum, so organisms will not leave any niche untried. There are two or three animals in the Great Salt Lake of Utah, notably the beautiful brine-shrimp; there is a considerable fauna in coal-pits; a few creatures are able to endure hot springs; more than one earthworm has been found thriving in a pocket of soil high up a tree; and there are at least a dozen animals that make a home of a pitcher-plant. One may almost say that there is no place where the voice of life is not heard. The gutters of houses; the water-pipes of a city; the insides and outsides of other living creatures, both plants and animals; the Arctic regions; the Deep Sea; the Sahara; the hollow caves unsunned; the lofty shoulders of Mount Everest; the rapids above the Falls of Niagara; beneath the snow of the high Alps; under many feet of ice on the Antarctic shore—can one think of any place where animal life is not represented? To one of the strange minor haunts of life, namely the waters under the earth, we wish now to turn.

There is no little variety amongst the waters under the earth, for they include the deep circumscribed wells, the extensive cavernous ponds and even lakes, and the subterranean streams which flow for miles in darkness. Every one remembers how 'Alph, the sacred river, ran Through caverns measureless to man Down to a sunless sea.' But besides the larger waters there are what might be called the subterranean capillaries, consisting of narrow channels, rarely more than two fingers in thickness and often much less. They are not so sensational as the underground rivers nor so impressive as the expanse of dark water in a large grotto, but they play an important part in the circulation of water, and they have a micro-fauna of their own.

What are the main peculiarities of the subterranean waters? The first is darkness, and that implies an absence of green plants except in so far as these may survive for a short time after being casually introduced. It follows that the life of the subterranean waters is not self-supporting; the organic matter which animals require must come from outside. In this respect the conditions are like those of the Deep Sea, with its eternal night. Also correlated with the darkness is the usual absence of pigment in the animals of the subterranean waters, for light is in many cases a *sine qua non* for the development of pigment. It is well known that the wan newt called *Proteus* (p. 478), that lives in the waters of the Dalmatian caves, becomes darkly pigmented in a week or two when it is transferred to a normally lighted aquarium. Another correlate—we do not say consequence—of the darkness is the frequent degeneration of the eyes; and it is important to remember that if the larval forms of the normally blind Proteus are reared under red light in the laboratory, the eyes that in darkness do not reach the surface, but remain arrested in develop-

ment, are stimulated to continue as ordinary eyes would, and actually acquire some power of vision. In the light—the quality of redness is a detail—the blind newts receive their sight. We have diverged, pardonably perhaps, on a side-path; but our point was that with the darkness of the waters under the earth we must associate: (1) the absence of green plants and the economic consequences of this for animal life; (2) the rarity of animal coloration in the native animals; and (3) the frequency of 'small eyes' or 'no eyes' in animals whose open-water relatives have eyes well developed.

The fundamental food-supply of the animals that make a home of the underground water is afforded by the organic crumbs that are swept in—fragments of plants, drowned worms, slugs, and insects, the fine débris suspended in the water, and an occasional living organism in a more or less moribund state. Investigations of the fine precipitate that accumulates on the floor of subterranean pools have shown that the organic dust and the minute organisms count for a good deal, but there is no doubt as to the general scarcity of food. In some measure, of course, the troglodyte aquatic animals feed on one another; the conjugation of the verb 'to eat' never ceases.

Another general feature of the underground waters is the uniform coolness. Year in, year out, the temperature of the water remains about the same, near the annual average for the surrounding region. 'Monotonous' is the word for the waters under the earth; they are marked by an uninterrupted night, a steady coolness, and a sparse supply of food.

The tenants of the dark monotonous waters may be grouped in three contingents. First, there are those that show special adaptations for this particular haunt of life, and are seldom or never seen anywhere else. In illustration may be mentioned the cave fishes with degenerate eyes, and the blind Proteus already described. Secondly, there are those animals that thrive in the dark waters but are also common elsewhere, as may be illustrated by the freshwater crayfish and not a few other crustaceans. Thirdly, there are the casual visitors that are not much incommoded by being swept into the darkness, such as some of the brook-leeches and freshwater molluscs. The three groups have received various names, such as troglobionts, troglophils, and trogloxenes.

The population is so varied and the adaptations to the peculiar conditions are so finely graduated that it is not easy to set forth the characteristics of the organisms of the dark waters, but there is a frequent tendency to (*a*) rudimentariness of eye, sometimes involving actual blindness; (*b*) a reduction of pigment, sometimes leading to translucency; (*c*) minuteness of size, which may be ascribed perhaps to the cramped conditions, and to the fact that it is easier for small

animals than for big ones to find their way into the bowels of the earth. It is often said that the animals living in cave waters show in compensation for reduced eyes an increased development of structures that are sensitive to chemical and mechanical stimuli, but, as a matter of fact, there are very few illustrations of this. A good instance is to be seen in the fish *Amblyopsis* from the Mammoth Cave, which shows a remarkable development of the lateral line organs that are sensitive to currents and changes of pressure in the water; but, so far as we know, this is an exceptional case. The expected does not always happen.

As to the origin of the aquatic troglobionts, some have been swept in from the surface waters and others have probably gone in of themselves. Many of the small crustaceans, for instance, have doubtless been carried in, and have found the conditions of subterranean life endurable, while the cave fishes and the blind newts (*Proteus* and *Typhlomolge*) have probably been active explorers that preferred obscurity and safety to the glare of day and a life of adventure. One of the most interesting facts in regard to the thoroughly established tenants of the waters under the earth is that while some of them, like the newt *Spelerpes*, are as it were new-comers, differing but little from their relatives in the open, others are relicts of great antiquity, such as the crayfishes of the genus *Cambarus*. On the whole, the troglodytes are slow-growing, conservative antiques.

'The Sea's Abundant Progeny'

One of the founders of the science of oceanography was His Serene Highness the late Prince Albert I of Monaco, and he was also the founder of the museum and aquarium there, opened in 1910. An initial difficulty was to find a site, for the old town of Monaco is built on the circumscribed summit of a great rock. Many of the streets are picturesquely narrow and tortuous. So the prince had the happy idea of building out on the sea cliff a great edifice that would encroach on nothing. Thus a great part of the building is supported on massive piers of fine-grained limestone, some of which rise from near the level of the water to a height approaching two hundred feet. Through a thick plate-glass circle in the floor of the aquarium-level the visitor can look down on the blue sea breaking on the rocks far below—a startlingly beautiful sight.

The highly successful aquarium at the London Zoo, with plenty of brains behind it, has captivated a large public, and who can wonder? Marine animals alive are for the most part 'joys for ever.' Their beauty of form is enhanced by the beauty of movement and beauty of colouring—two expressions of beauty which are lost in museum

specimens. Moreover, we can watch the creatures in an aquarium, with the light shining through the water, even more effectively than in a shore pool. In any case, the Monaco aquarium is a beauty-feast and a miracle-play and a course in zoology combined. It is not very large, but it is practically perfect; the water is luminously clear, and the animals are in perfect health; there is very little repetition, and yet a wide representation of what Spenser called 'the sea's abundant progeny, whose fruitful seede farre passeth those on land.'

What a gamut of forms! Common eels, conger eels, and the big *Muraena* which the Romans held in high esteem, there they are together, displaying their **thigmotropism.** In other words, they are uncomfortable unless they are touching something with a large fraction of their body. We see one ensconced in a U-shaped pipe, with the head protruding at one end and the tail at the other.

How different from these are the whimsical sea-horses, perched like living marks of interrogation among the weed, and then slowly sinking downwards till they are hanging like monkeys by their prehensile tails! The rapid quivering of the median dorsal fin is pleasant to the eye, and our humour is tickled by the swollen breast-pocket in which the father fish carries about his family.

What a contrast between the sedentary sea-squirts, like translucent leather water-bottles, and the restless sepias swimming beautifully with their undulating fins, and showing zebra-like stripes above and emerald green below! They fold the eight short tentacles in front of the mouth, so that the anterior end has a quaint resemblance to the head of a resting elephant. At the critical moment the two long tentacles are shot out on a hapless crab. When we were there, all the octopuses in the aquarium were simply lurking in holes among the rocks, very inconspicuous in their protective coloration. Perhaps the light was too strong for them.

The longer we look, the more animals we see. There, for instance, is the fish called the 'star-gazer' (*Uranoscopus*), quite hidden in the sand save the two watchful eyes on the top of its head. Many other fishes here represented, such as soles and weevers, have this habit of burying themselves. The biggest fishes in the aquarium are the heavily built, thick-lipped sea-pigs, and yet they take on the colour of the substratum so perfectly that we hardly notice them as they lie huddled together. They become surprisingly active, however, when the keeper drops in some food! It may be noted that these somewhat unattractive creatures (*Scorpaena porcus* and *Scorpaena scrofa*) form an essential part of the very attractive 'bouillabaisse'—the characteristic fish-stew of the Mediterranean seaports.

Another cloak of invisibility, which we have noted under 'Shifts for a Living,' is well illustrated in the Monaco aquarium, namely,

masking. There is a sand-crab, for instance, with a garden of seaweeds on its back—a 'walking wood of Birnam.' It fixes them on with its forceps and they actually grow. Another crab is camouflaged with little pieces of sponge and another with zoöphytes. One of the hermit-crabs has its borrowed whelk shell covered all over, save the mouth, with an orange-coloured sponge (*Suberites*) which must very effectively mask the crustacean's real nature. The sponge will be left alone by most animals that know the ropes, for it has a strong smell of iodoform and it is riddled with microscopic needles of flint. Subtler still is the mutually beneficial partnership established between several kinds of hermit-crab and several kinds of sea-anemone. It is rather surprising to notice what looks like a sea-anemone tearing across the floor of the aquarium at a great pace!

In striking contrast to the self-effacers are the self-advertisers, such as a brilliant coral-red **starfish,** another in livid crimson, an orange-red sea-squirt, the fascinating rainbow wrasse, the *Muraena* adorned with old gold, sea-anemones in red and green, the blue wrasse and the red gurnard, tube-worms with superb tentacles like flowers, and, finest of all in some ways, a translucent, reddish sea-pen, with which one would like to write Natural History. As a sensation for the end of our visit we left the *Torpedo* or electric ray, which was advertised as ready to give the adventurous a shock. But when we came to its open, shallow tank we found that it had already given too many shocks that forenoon and was feeling somewhat indisposed. Like most organs, the Torpedo's electric battery requires to be charged after it has been active several times. Even our heart has its momentary rests between its beats.

Pond-life

There is not in a pond at first sight any strong suggestion of the romantic. A stream lives, even though it is narrow enough to be crossed in a stride, but a pond sleeps. A pond suggests the circumscribed and the commonplace. A pond is often, though not necessarily, artificial; and though it may be a mile long, it differs from a lake in being always shallow. If it is deep, it is not a pond, but a tarn, a lochan, or a quarry-hole. Yet Natural History has failed of its purpose if it does not disclose the romance of the pond.

We wish we could say that there are beavers in the particular pond we know best, or even otters, but the only mammals we have seen in *our* pond are **water-rats.** Interesting creatures, however, with flat, broad head, rudder-like tail, thick fur, clannish habits, able to swim and dive, burrow and run. They feed chiefly on water-plants, with small animals, such as insect larvae, for relish; they often make excursions on land to the farmer's fields, but the harm they do is trivial.

Water-voles, to give them their pedantically proper name, are creatures of the day, and we sometimes see them eating daintily with a suggestion of squirrels in their pose, or transporting their tender young from birthplace to burrow. The father is unusually parental, and another pleasant feature in his character is his **monogamy**. We are not trying to make out that water-voles are striking or sensational in their ways, but he must be dull indeed who fails to discover any romance in their quiet lives.

Uneventfulness marks the everyday life of the **pond-mussels**, which plough their way tediously in the mud at the bottom, or rest there with most of the shell buried. The greater part of their energy is given up to sustaining currents of water in and out of the valves, through the instrumentality of myriads of ciliated cells which cover the food-wafting gills. They feed at a low level on microscopic débris and organisms in the water. Unromantic it all sounds, yet think of the mother mussel's liberation of pinhead larvae when an inquisitive **minnow** comes swimming slowly past. Jerking their minute shell-valves and exuding threads of glue, the **larvae** or **glochidia** of the pond-mussel fix themselves to the minnow, and sojourn on it for a while in a sort of temporary parasitism. After undergoing a profound change in bodily architecture, they drop off from the minnow, which may by this time have passed down the mill-race to a quiet stretch of the river. Think also of the pearl that is occasionally found in the freshwater mussel, which is, sometimes at least, the sepulchre of a parasite, the microscopic larva of a tapeworm or a fluke, the adult of which lives in some water-bird! How unexpectedly life is linked to life; and this is romance!

We have always admired the spirit of the Abbé Trembley, who was the first to make a careful study of the freshwater polyp, which he called *Hydra*. The little creature which he discovered (or rediscovered) in a pond about 1740 is only about half an inch long, and is as thin as a needle, yet he called it 'Hydra' after the mythical monster with which Hercules contended. The allusion was to its defiance of wounds, for the more Trembley cut up his Hydra, within certain limits, the more Hydras he got. But our point is simply to admire the wisdom of discerning a giant Hydra in a minute polyp, a world in a grain of sand.

Sometimes the farmer lets all the water out of our pond, and there is a great squirming and wriggling of **eels**. Big fellows, some of them, up to seven or eight years old, as the rings on their scales plainly show; soon they will be setting off on their long journey down the river and through the wastes of the ocean to near the Bermudas, where they spawn and die. A polyp is a Hydra; an eel is a great explorer—pointing on to Columbus!

Talking of eels reminds us of the **hairworms** (e.g. *Gordius*) we sometimes find in the pond, moving freely like swimming snakes or coiling about amongst water-plants. These are the creatures that schoolboys of bygone unsophisticated days believed they could obtain by leaving horse-hairs to soak in pools. What a strange life-history they have! The eggs are laid in strings or clumps on water-plants; the hatched-out larvae bore into the young stages of alder-flies and the like; these are devoured by water-beetles within which the worms mature; thence when fully ripe they emerge into pond or pool, where the sexes meet and pair, often tying themselves up into Gordian knots.

Our pond is fringed on one side by water-willows, among which moorhens are at home all the year round, and sundry visitors at appropriate seasons. On the branches of the willows in June we have often watched the final disrobing of certain **may-flies** or ephemerids —the only insects that moult their cuticle after they get wings. What a romance is the familiar story! There are two or three years of larval life, during which there is feeding, growing, and moulting in repeated sequence; and then there are two or three days—sometimes a single evening, in one case a single hour—of aërial life in which hunger is altogether swallowed up in love. How the physiological see-saw swings between nutritive and reproductive activity! What romance!

Not in the pond, but in a pool not very far off on the moor, there is still to be found the silken dome or tent of the **freshwater spider,** which bears the beautiful name of 'silver-swimmer,' *Argyroneta natans* (p. 360). Here, again, is romance, for we see a thoroughly terrestrial animal, given to breathing dry air, yet tackling and solving the problem of living under water. As the spinster pulls herself down along a special thread which is attached to water-weed on the surface and to a stone below, she glistens with the minute bubbles of air that are entangled amongst the hairs of her body. She strips these air-bubbles off underneath the sheet of her sub-aquatic web, and thus there is eventually formed a dome full of dry air, in which the young are hatched out and reared. Under the pressure of circumstances, or moved by some spirit of adventure, animals have not only sought out many adventures, but have essayed the conquest of haunts that are sometimes the last that one would have expected. This is well illustrated by the life of the pond, in which many creatures have found a place of refuge, affording a measure of safety and yet not so easy as to cause retrogression.

To call the roll of pond animals would take a long time. Think of water-shrew and newt, water-snail and mite, the water-hen and the caddis-flies, the carp and the green sponge, the water-fleas and the water-worms, and all the multitudinous world of the microscopic.

A pond is a much less hazardous haunt of life than a swift stream, and the animal population is much greater. But although the conditions make on the whole for peace and prosperity, we have perhaps said enough to suggest that they are anything but humdrum. There is romance even in a duck-pond.

Arctic Survival

We grumble a bit at a few days of wintry weather, and as the years pass we grumble more, for as we grow older we seem to become less perfectly warm-blooded or **homoiothermal.** That is to say, we seem less able to meet the loss of heat by producing more. We shiver uneasily, with something of the dread of 'bad sailors' who are afraid lest the passage across the Channel may prove too long for them. A few days of bitter cold we can endure, but we do not like to think of its lasting very long. We are not sure that we can survive. We sometimes wish we could hibernate like hedgehogs and hamsters. At this stage we shiver again, which means that so many nervous commands are being sent to our muscles to produce more heat that they contract in an irregular, confused sort of way.

When we are 'feeling the cold,' the time is ripe for thinking about Arctic animals which have to endure for perhaps nine months a dark winter far colder than we ever experience in Britain. How do the Arctic animals stand the cold, especially the mammals and birds which are warm-blooded or homoiothermal like ourselves? What is the secret of Arctic survival?

One of the simplest adaptations is to have a thick pelt or plumage, which acts like a non-conducting quilt and lessens the loss of heat into the cold air. In the Arctic fox, the Arctic hare, and the lemming there is a soft, silky outer fur covering a woolly undercoat. In the reindeer the strong outer hairs are thicker at the tip than at the conically narrowed root, with the result that they adhere closely and imprison air in the interspaces. They are said to make the best stuffing for swimming-jackets, but their use to the reindeer is to deflect the snowflakes and drops of rain so that the shorter undercoat is not wetted. It is interesting to notice how dry Shetland ponies keep, even when the rain is dripping off the outer hairs. In the musk-ox of the far north the outer hairs may be two feet or more in length, and they serve to keep the internal wool comfortably dry. There is a touch of perfection in having hairy slippers, as in the Arctic fox and polar bear, or feathery toe-gloves, as in the snowy owl and the Spitsbergen ptarmigan.

This device of putting on thick clothes has been exaggerated by man, who puts many a pelt outside his own. Dr. Leonard Hill tells

good-humouredly of the disrobing of a patient who removed something like a motor coat, a top-coat, a tweed jacket, a Jaeger jersey, a waistcoat, a soft shirt, and a woolly undervest. One does not need to be a physician to know that the patient was 'feeling the cold.'

Another Arctic device that man sometimes imitates is to accumulate a thick layer of fat beneath the skin. This serves to conserve the precious animal heat, and it can also be used as a source of calories in the severely rationed cold months. Most mammals have this fatty layer, or *corpus adiposum*, as a normal deposit beneath the skin; but it is well known that the deposit is absent or almost quite absent from the common hare. This makes it peculiarly interesting to notice that the Arctic hare in more rigorous conditions accumulates a thick *corpus adiposum* in the short summer and burns it slowly away during the long winter. It is this fatty layer that is exaggerated to form the blubber of whales and seals, which certainly need a good non-conducting enswathing in the icy waters.

Of external storing there are not many instances among Arctic animals, but both the banded lemming and the Hudson Bay lemming are said to hide numerous cut pieces of root and the like under stones. The clever Arctic fox sometimes makes a *cache* of ptarmigan and other birds when his hunting has been lucky. But much commoner than storing is some drastic change of diet, as may be illustrated by the polar bear turning under winter's compulsion from seals to fishes or even to plants; or the reindeer coming down to eat the jetsam of sea-grass on the shore; or the starving Arctic fox condescending to mussels exposed on the rocks at low tide. Queer things happen, as when a reindeer swallows a lemming.

No one can picture Arctic mammals without noticing the number of white species on the short list. We think of Arctic fox, Arctic hare, polar bear, with their counterparts, like the snowy owl, among birds. Moreover, the chestnut summer stoat becomes the snow-white winter ermine, and the two kinds of lemming mentioned above put on a white robe in winter. Even white freaks, like white wolves, are of commoner occurrence the further north we go.

In our judgment the right way to look at a biological fact like Arctic whiteness is somewhat as follows: Dark pigments, like the melanins, are very common among mammals and birds; they are by-products of the ordinary chemical routine or metabolism of the body. They may arise, for instance, from the breaking down of the amino-acids, which are derived from the protein part of the food. In certain environmental and nutritive conditions these melanins are not formed, and instead of pigment-granules there may be gas-vacuoles in the hairs or feathers, with the result that there is a total reflection of the light, and the animal has the quality of whiteness. The intimate connection

between the Arctic conditions and the non-production of melanins is still obscure; but if the occurrence of whiteness is a new departure that may be reasonably expected to occur in Arctic conditions, the way is open to show that this is a variation which would tend to survive. It would do so primarily, because a warm-blooded animal with a white dress loses in very cold environment less of the precious animal heat than if it had pelage or plumage of a dark colour. Then is the time to refer to a possible secondary advantage, that the white animal may be inconspicuous to its enemies and its victims against a background of snow. This may be sometimes true, as in the case of white ptarmigan and white hares, which are well camouflaged against the snow, but it is a mistake to begin with such considerations, not only because the physiological aspect comes before the teleological or utilitarian, but also because the protective coloration is often difficult to prove. The Greenland falcon and the snowy owl are beautifully white, but they have no enemies against which they need to be camouflaged, and as they usually catch their victims in an exceedingly rapid swoop, it is difficult to believe that the capture is appreciably facilitated by the white dress. But when an animal is keeping up its own temperature by its own production of heat, in conditions of austere rationing, it is easy to understand that any lessening of the superficial loss of heat may have survival value. That reduction of the loss of heat is what a white dress secures.

It is easy of course to bring forward instances of dark-coloured Arctic animals, such as the musk-ox and the polar raven, but these raise no particular difficulty. Their survival depends on other qualities. Thus the musk-ox is a good illustration of compactness of build, which lessens the proportionate amount of vulnerable, e.g. cold-numbing, surface. It is of distinct value in very cold surroundings to have a superficial reduction of ears, neck, legs, and tail. Man has arrived at some dim awareness of this, for in default of being able to reduce the surface, he wraps himself up so well that we often can see nothing but his eyes, and then we do not know who he is.

The Tundra

North of the Arctic Circle in Europe and Asia lies a great tract of almost treeless land known as the 'Tundra,' and it is represented by the 'Barren Grounds' of North America. Much of it is swampy; yet most of the water is snow and ice for the greater part of the year. As it is also sour with humic acids, it is not very available for the tundra plants, which are thus apt to suffer from drought. As Miss Haviland points out in her masterly book, *Forest, Steppe, and Tundra* (Cambridge, 1926), there are interesting correspondences between the cold tundra

and the warm desert. In the latter there is physical drought, in the former it is physiological. In both there is a short vegetative period, determined by the rainy season for the desert, and by the brief summer warmth for tundra. There are smothering snowstorms in the tundra, sandstorms in the desert.

The oasis in the tundra is where there is least water, in the desert where there is most. It is striking that tundra plants should be adapted, like desert plants, against drought, in having a large root system, restrained and compact aërial parts, often concealed stomata, and leaves succulent or leathery, woolly or waxy. One must recognize the possibility of water everywhere, yet not more than a drop for the plants to drink.

What with the physiological drought, the tenacious grip of the frost, month after month, the fall of the winter temperature to —50° F., or even —70° F., and the bitter winds, the tundra must be one of the most inhospitable haunts of life. It would be flattery to compare its million square miles of desolation to the dreariest, squelchiest, and most cruelly stripped moorland plateau in Great Britain. Yet every traveller has told us of the irresistible transformation scene towards midsummer, when the frost relaxes its grip and the snow has melted before a sun that does not set for quarter of the year. The air is warmed and the vapour rises like steam from the ground; flowers spring up in profusion—not only dwarf willows and low saxifrages, but tall lupins and gay poppies. Insects, such as mosquitoes, appear in dense clouds, and the migrant wading birds like plovers congregate to change one kind of flying flesh into another. Nowhere else in the world is it so clear that insects turn into birds! And by and by the young birds, if not their parents, are reincarnated into mammals, as the cheerful Arctic fox well knows.

The authorities recognize four 'formations' in the tundra. First, there are the vast tracts of the drier high tundra, with little vegetation save lichens and coarse grass, with almost no flowers, and very few birds. Second, there are the flooded flats near the rivers, really including, as Miss Haviland points out, two areas: (*a*) the dwarf willow-scrub, all that the tundra has to show in the way of forest, and (*b*) the moss-bogs with *Sphagnum* and lichens but no flowering plants, save marshwort and sedges. In both areas — the well-drained and the water-logged—there are many courting and nesting birds during the short summer; but the mosquitoes make the moss-bogs an inferno.

The third formation includes the southern slopes of the uplands and ridges. Being well drained and in summer well warmed they are 'flower-oases,' mostly with low-growers like saxifrages, forget-me-nots, starworts, and dwarf buttercups, but occasionally with more ambitious types like globe-flower, Jacob's ladder, larkspur, and ragwort. A

fourth formation, distinctive but of minor importance, includes fertile hummocks breaking the monotony of the plateaux and marking old camping-grounds or the dens of the Arctic fox. But it is only in the short summer that the tundra can be said to be very markedly differentiated into 'formations'; in winter there is a monotony of life-saving snow and of long-lasting darkness.

What are the outstanding biological features of the tundra? Very noteworthy is the relative poverty of the fauna and flora, for, though there is often an abundance of life, there are not very many different kinds. There are multitudes of lemmings and great herds of reindeer, but there are not many different species of mammals altogether. When we have noted the lemming, reindeer, Arctic fox, Arctic hare, wolf, and ermine, we are nearly at an end of those that are common; for we must not include explorers from the forests further south, like the bear, or from the mountains, like the musk-ox. Similarly, though there are immense numbers of birds, there are not many different species, and all are migratory.

Most of those that succeed, like the plovers in the wide sense, have precocious young ones with rapid development and gregarious habits, whose welfare is ensured by the highly developed carefulness of both parents. They thrive on the mosquitoes, both larval and adult, in the swamps, and on the small fry such as water-snails in the river flats. Many of the animals and the plants of the tundra are able to shorten their reproductive period, so that the more critical events are all over in the short summer; but they must also be able to stand the strain of the continuous sunshine, unrelieved save by clouds and mist. Only certain constitutions can stand this. By the interpolation of a quiescent chrysalid stage most of the tundra insects are able to extend their life-history over two summers.

From the relatively small number of different types it follows that most of the 'nutritive chains' will be short. The fox eats the willow-grouse which eats the willow buds. The plover eats mosquitoes, which do most of their feeding when they are aquatic larvae, and sweep animalculae and microscopic particles into their mouth. Lemmings are vegetarian, and they are devoured by foxes and birds of prey. Reindeer feed mainly on lichens, and they are hunted by wolves.

Compared with many of the nutritive chains in other haunts of life, these are short, but Miss Haviland points out that the interactions are often subtle. If plants become scarce the lemmings suffer, and the foxes have to levy a heavier tax on the birds. 'Man is the connecting-thread in a web so vast that the failure of lemmings in the Taimyr is reflected in the markets of London and Paris as a rise in the price of fox-skins.'

The struggle for existence in the tundra is terribly keen. This is

partly because the environment is so severe, as in its lasting frost, its blizzards, its long night, and its water-logged soil; partly because the number of different types of competitors is relatively small, so that there are crowds of claimants for the same things; and partly because large numbers of similar living creatures are congregated in the same place at the same time.

Sometimes, as among the carnivores, the competition between fellows of near kin must be very intense, when there is not enough of food to go round. But there is also the struggle between foes, such as fox and goose, wolf and reindeer. And behind all is the struggle between the living creature and the callous physical environment. When the food-supply is exhausted it does not necessarily follow that the struggle between the members of the same species will become extremely acute, for often there is little beyond jostling and hustling that they can do to one another. The lemmings cannot eat one another when the vegetation is exhausted!

It must also be kept in mind that in many cases the major part of the struggle is in the past, for adaptations have been established and are shared alike by all members of the same species—effortless adaptations which greatly lessen the intensity of the struggle in the present. Thus the lemmings burrow beneath the snow; the reindeer use the brow tines of their antlers, present in both sexes, as 'snow-shovels'; the ptarmigan put on a white dress in winter; the summer visitors migrate to the south.

But even after we allow for all the adaptations that we know and the hundreds that are not yet discerned, there is no doubt that the tundra is a difficult haunt of life where the struggle for existence is very keen. It is true that for the nine months of the winter night the tundra life is for the most part asleep under blankets of snow, but this only accentuates the intensity of bustle and hustle in the three-months day of summer

The Tropical Forest

What we should try to do is to put a girdle round the globe and see the various floristic and faunistic zones in their proper places, as we journey on the magic carpet from pole to pole. From the Arctic Ocean to the tundra with its lemmings and foxes, its wintry deserts, and its spring exuberance of flowers and mosquitoes and migrant birds from the south. From the tundra to the stern northern forests, largely coniferous, where so many furred animals are at home. Then comes the zone of steppe country and prairie, the haunt of cud-chewing herds. But the grassy plains are interrupted by mountain ranges where some animals are insurgent adventurers, and others timid

refugees, and a third contingent relicts of the colder climates of long ago. Another interruption is the desert, with its drought-withstanding vegetation and with such animals as the elusive jerboas and gerbils, the swift antelopes and camels, and a plethora of lizards and insects. Then come the southern grass-lands like the Pampa; and we pass by various routes to the Antarctic Continent, which is so different from the shores of the Arctic mainland in the entire absence of land mammals, and the almost complete absence of land birds. But there is another great zone, namely the Rain Forest, or low-lying Tropical Forest, close to the equator. It is so overwhelmingly rich in plant life and so unfamiliar in its animal life that one does not know where to begin. But the essential features are portrayed in a masterly way in Miss Haviland's *Forest, Steppe, and Tundra*, and we take this as guide.

What are the outstanding physical features of the tropical forest in South America, in Central Africa, in Madagascar, or in Malaya? High, even temperature and abundant moisture count for most; and they have evoked a vegetation so luxuriant that it saves the situation for animals by affording shade. The abundant and well-distributed rains fill the air with persistent water-vapour. The forest is like a steamy hothouse. Though it is not a land of eternal summer, the seasons are not sharply punctuated. There are swamp jungle, higher-lying forest, and other zones, yet there is notable uniformity within each association. The most notable vicissitudes are the terrific rain-storms, which often bring about a widespread and indiscriminating destruction of life. 'An avalanche of water crashes down, blotting out surrounding objects, and, as it seems, sweeping the very breath from the nostrils, bewildering and benumbing the senses.'

As regards vegetation, the outstanding fact is its manifoldness, and in particular the huge number of different kinds of trees. The tropical forest has less rather than more colour and glamour than our own, but whereas a good mixed wood at home will hardly show more than a dozen different kinds of trees, the forest of Cameroon, for instance, has over 400 different species, besides twice as many shrubs. A second feature is the density of growth and the severity of the struggle for existence—so well pictured in R. L. Stevenson's *Woodman*—the struggle for space and for light. This is indicated by the large number of climbing plants and perched plants or epiphytes. These suggest a third feature, that there is tier above tier of vegetation. There is very little undergrowth because of the dense shade, but higher up, as Humboldt put it, 'forest is piled upon forest.' As Miss Haviland says: 'Each tree is a microcosm, the prop and sustainer of a host of living things which in many cases are not living there fortuitously, but are delicately adjusted to their environment.' She

aptly compares the tropical forest to a sea, with different sub-faunas at different levels: and there is this further resemblance, that the waves are mostly among the tree-tops, while the lower depths tend to be stagnant.

There are many characteristic forest mammals, such as the leopard, the okapi, the tapir, some wood-antelopes, the tree-sloth, and various kinds of monkeys. Birds, such as parrots and hornbills, are so abundant that Beebe counted over four hundred species in ten square miles of British Guiana forest, about as many as there are on the whole British list. Tree-snakes and arboreal lizards abound. It is the paradise of tree-frogs. At different levels there are insects galore, gorgeous butterflies, golden beetles, weevils like jewels, noisy cicadas, and dancing fire-flies. But if we make big spatial and temporal exceptions for the insects' nocturnal concerts and the tree-frogs' serenading, the tropical forest is singularly quiet, so that the sudden breaking of the silence by a screaming parrot or an expostulating monkey is disproportionately startling. Although there is a very rich bird fauna, there is much less singing than in a small copse at home. Especially during the day there is an almost oppressive silence in the rain forest. As Professor Hesse says: 'The monotonous sound of dripping water-drops is only now and again interrupted by the cry of some surprised bird, the cooing of a brooding dove, or the humming of a swarm of bees. Deep silence reigns all the day long in the tropical forest.'

Some naturalists have spoken of the poverty of the animal life as compared with the plant life, but this is largely a mistake, as Beebe's censuses prove. The fact is that many of the forest animals are cryptozoic, spending their days in retirement and effacing themselves when disturbed. Moreover, the forest is swarming with examples of protective coloration and mimicry. In hundreds of cases the animal has become like something else. Furthermore, to appreciate the richness of the animal life in the tropical forest the observer must stand quietly for hours on end; and there are various reasons (such as ants!) why this is not easy.

The question whether the struggle for existence is fiercer in the tropics than elsewhere is answered by Miss Haviland in the negative. 'Perhaps an animal is liable to attacks by more enemies than elsewhere, but, set against this, famine, drought, and cold are unknown. The seasonal changes are slight compared with those elsewhere, and there are always warmth, light, shade, and moisture.'

On the other hand, in the wide Darwinian sense the struggle for existence includes all the responses that organisms make to environing difficulties and limitations; and while there may not be in the rain forest a very intense competition around the platter of

subsistence, there may be a very keen endeavour after well-being. We suspect that this is so, and we base our conclusion on the extraordinary frequency of such protective adaptations as mimicry and other modes of disguise, and on the large number of linkages or interrelations that have been established, such as the concatenation of leaf-cutting ants, a nutritive mould, and the trees visited; or the triple alliance between certain little beetles, certain mealy-bugs, and the leaf-stalks of the *Tachygalia* tree. The web of life has many a tangle in the Tropical Forest, and this spells 'Endeavour.'

The Underworld

After plants had in some measure prepared the way, animals began to invade or colonize the dry land, and it seems reasonable to distinguish three great invasions. There was the worm invasion, which led on to earthworms and consequently to the making of vegetable mould and the great improvement of the soil. Secondly, there was an invasion on the part of air-breathing jointed-footed animals, such as centipedes and millepedes, leading on to insects and consequently to the establishment of the most important linkage in the world, that between flowers and their welcome winged visitors. For the cross-pollination of flowers by insects means an improvement not only in the quantity, but also in the quality of the seed. Thirdly, there was the amphibian invasion, which we see recapitulated every year when the small frogs migrate from the ponds to the fields. This amphibian invasion led to the evolution of reptiles, whence sprang both birds and mammals.

But after adventurous pioneers of various races of animals had reached the promised land, they discovered that it was not always flowing with milk and honey. Their movements were restricted to one plane; oxygen was available in larger quantity, but it was less readily captured than in the water; it was much more difficult to secure the safety of the eggs and the young. There were likewise great risks of drought and frost and local overcrowding. So it became necessary for some of the colonists to trek once more, and this is how we should look at the attempts that have been made to get off the surface of the earth—on to trees, into the air, into caves, and underneath the ground.

Let us consider for a moment the last adventure. Earthworms probably sprang from a freshwater stock, but they became subterranean and had for a while a golden age in the underworld. After a time, however, their kingdom was invaded by the pertinacious, poisonous centipedes, later on by carnivorous burrowing beetles, much later by moles; so that earthworms are now a much-persecuted race. They have had to resort to a very cryptozoic life, adding to their burrowing habits a purely nocturnal above-ground activity.

Until we look into the matter we do not perhaps realize the number and variety of subterranean animals, living like sappers and miners out of sight. There are soil-amoebae and soil-infusorians, sometimes of agricultural importance, for instance by devouring large numbers of the bacteria which bring about putrefactive and other useful chemical changes underground. There are a few subterranean planarian worms, and very numerous thread-worms; there are larval insects galore and not a few adults; some snails and slugs burrow deeply. The African mud-fish may spend more than half the year in a lethargic state in the dry mud, and there are various other fishes which can live out of water. The old-fashioned worm-like amphibians, known as *Caecilia*, have found refuge underground, and there are a good many burrowing limbless lizards and burrowing snakes. The sand-martin deserves to be called a burrowing bird, and the same may be said of the burrowing Australian parrot, *Stringops*, which has given up flight altogether. Among burrowing mammals may be mentioned the marsupial mole of Australia, the archaic golden mole of Africa, the familiar gentleman in the velvet jacket, the prairie-dogs, the rabbits, and the voles.

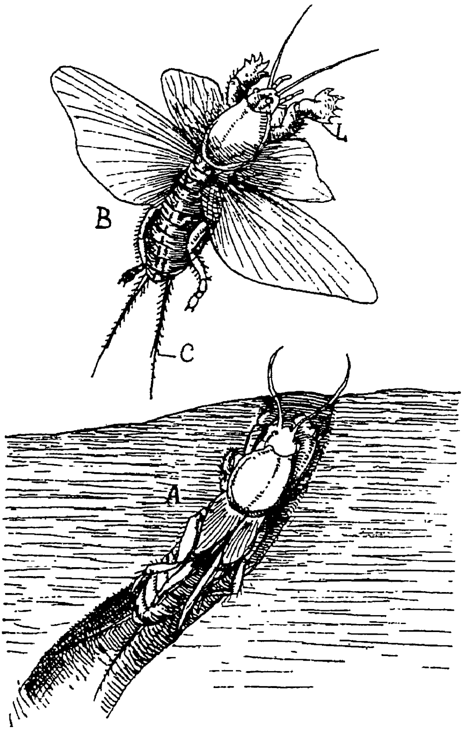

FIG. 306. MOLE-CRICKET (*Gryllotalpa vulgaris*)

A, insect in its burrow; B, insect with appendages displayed. L, modified leg; C, anal cercus.

It would be interesting to show how well adapted many of these burrowing creatures are to a subterranean life, and how the same sort of fitness has been independently attained by animals which are not related to one another, as is plain enough when we compare a mole-cricket (Fig. 306) and a mole. But our present point is to indicate the literal truth of the phrase ' the living earth,' and to unify many of these

diverse creatures of the underworld in the light of the idea that the surface of the earth is a dangerous haunt of life—so riskful, indeed, that many animals have been trying for ages to exchange it for some other.

The Biology of Dust

When we sit during the day in a tree-shaded room penetrated by a sudden beam of light, we often see the motes in apparently countless numbers. They seethe up and down; they suddenly rush pell-mell in one direction as if they were living creatures on a stampede; they swirl in a vortex; and then they drift in a leisurely way hither and thither.

The familiar sight is not unpleasing, with its illusory suggestion of life—for all these mass-movements must be due, we suppose, to inequalities of pressure and temperature in the air of the room. We may not welcome the disclosure of multitudinous particles of dust in the room, or the thought that we are taking all this into our nostrils at least, and some of it, no doubt, into our lungs. Yet we reflect that the number of living microbes in well-sunned air is not large; and the fact seems well established that the transmission of infection by air-borne germs is not very common.

There is a pleasure in watching these swirling, rushing, drifting motes, because we know that we are actually seeing the invisible. When the room is well lighted they are not to be seen, yet we have only to close the shutters all but a chink to see the vast multitude. The explanation is much the same as in the case of the objects detected by the use of the ultra-microscope. We are not seeing the actual dust particles, for they are too small to be visible; we are catching the rays of light diffracted from their surfaces. Perhaps it may be permissible to say that we are seeing the mote's halo, which is much larger than the particle itself.

Just as there are in the waters of lakes and seas large numbers of invisible organisms, sometimes called the 'dwarf-plankton' or **nano-plankton**, able to pass through the interstices of fine silk cloth, so it has been proposed to speak of the **aëroplankton** of bacteria, fungoid spores, unicellular algae, microscopic egg-cells of animals, pollen-grains, yeast plants, and so forth. These can be caught and cultivated in glass saucers with some suitable nutritive medium like gelatine; and one cannot speak of such things without remembering that it was Pasteur who first realized and demonstrated the living dust of the air. When this living aëroplankton is caught and grown on a suitable medium it can be studied in detail without difficulty; but other methods must be used for the not-living dust, which consists of organic minutiae, mineral particles, and suspended droplets of water-vapour, and others of more complex composition. An old method, due to Pasteur, was to

filter the air through cotton-wool, which caught the solid dust particles. The cotton - wool was dissolved away, and the residue left in the vessel was then microscopically examined. Modern methods have been refined, and it is possible, for instance, through the late Dr. John Aitken's ingenious devices, to count the number of motes in any sample of air. Who can forget the famous contrast between a cubic centimetre of heavy city air with hundreds of thousands of motes and another cubic centimetre from the top of Ben Nevis which contained only one mote!

The mineral particles come from air-burned meteorites, from volcanoes, from readily weathered rocks, from factory chimneys, and so forth. Special operations such as crushing rocks or carving granite must add greatly to the mineral dust of the air. There are other products of imperfect combustion which cannot be called mineral, and some of these take the form of minute tenuous globules of some oily or tarry substance. It is interesting to inspect the not very recently polished glass tops of museum cases and to discover minute slightly coloured circles which seem to indicate the places where the infinitesimal bubbles alighted and burst. Of course all dust particles must eventually sink, but in the case of those that have a large surface in proportion to their weight, the frictional resistance in the air counteracts the pull of gravity. Moreover, crowds of dust particles coming to earth are often lifted again by an up-current of heated air, so that they begin their journey, or return journey, over, again.

Another kind of dust particle is organic but not living, for microscopical examination shows that the air includes many minute fragments of hair and feather, of leaf and flower, of husk and down, of clothes and carpets, and so forth. The dust of the air must be appreciably different at the time of the spring-cleanings when carpet-beating goes on so merrily.

Professor Molisch describes part of the surface of a drop of glycerine that was exposed for an hour to city air. Microscopical examination showed smoke particles, a wool fibre, a cotton fibre, a linen fibre, some starch grains from sacks of flour, a minute fragment of a wood fibre, shreds of hay from horse dung, a pellicle of leaf, some pollen grains of a conifer, several spores and mineral particles. In times of drought and wind the number of dust particles increases; in quiet, showery weather it is at a minimum. In the vicinity of man's operations the aëroplankton and the organic elements are most numerous; over the open sea they are practically absent; but mineral particles from cosmic dust or volcanoes may be well represented.

Returning to the aëroplankton, we must give a prominent place to the pollen grains of conifers and flowering plants. In places near fir woods there may be at the proper season such multitudes of buoyant

pollen grains in the air that 'sulphur showers' result; but after a few weeks the conifer pollen has quite disappeared, its place in the air being taken by that of grasses and cereals and other flowering plants. From the end of May to the middle of July there is an abundance of pollen from grasses, and from those cultivated grasses that we call wheat and rye and so on. Some poison which these contain finds its way into susceptible people in the process of breathing, and gives rise to the vexatious disease known as 'hay fever.'

In some cases the extremely irritant hairs of certain caterpillars form a troublesome part of the aërial dust, and not less curious and annoying are the branched, somewhat stellate, hairs detached from the young leaves (and, according to some authorities, the fruits) of the Oriental and American plane trees, *Platanus orientalis*, and *Platanus occidentalis*. As Dioscorides and Galen noticed very long ago, these irritant plane hairs affect sight and hearing and voice. Their evil influence, unanalysed so far as we are aware, brings on severe coughing and inflammation of the air-passages, but only certain people are very susceptible, just as is the case with hay fever.

Evidently, then, a somewhat heavy indictment can be preferred against the dust of the air. So we hasten to hear the other side. The diffuse illumination of the atmosphere is due to the scattering of the sunlight by the floating motes; the blue sky is largely the result of the light-scattering effected by dust particles of the higher layers; the rose of dawn and the splendour of sunset must also find their scientific interpretation in terms of dust, and the same cause helps to some extent in giving us the prolonged twilight of summer evenings in the north. So there is much to be said for dust—in its proper place.

Fauna of a Moor

By a moor is meant a stretch of ground where much peat has been formed, where there is abundance of vegetable organic matter (humic acid and the like) in the soil, but little lime, a scarcity of bacteria and earthworms, and poor drainage. As every one knows, there are only a few plants that do well on the typical moorland, and these do well because of some peculiarity such as the partnership between the heather and an interpenetrating fungus. Even in the better parts of a moor, where grass is beginning to make a carpet, there is poor pasturage. Plants like eyebright and yellow rattle that seem to flourish are thieves on the roots of grasses and the like, which can ill afford to be robbed. In wettish places there is often a lot of *Pedicularis* or lousewort, which is said to infest the sheep with lice. We have often wondered at this name, lousewort. Is it possible that the 'lice' referred to are the sheep-ticks (*Ixodes ricinus* and *Haemaphysalis punctata*),

which are particularly common on sheep on hill pastures? It is known that sheep are infected by the ticks climbing up, both in their larval and later stages, from among the herbage. But, of course, ticks belong to the *Acarina* among the Arachnids, whereas lice belong to *Anoplura* among the insects. Or may it be that sheep fed on poor moorland pasture, where lousewort abounds, are very apt to get out of condition, and thus specially liable to become 'lousy'? The lousewort gets the blame, though its only connection with lice in sheep is that it is an index of poor pasturage, where sheep are apt to sink into the constitutional condition that makes it easy for them to become badly parasitized. Frankly, we do not know. But it has been shown repeatedly that improvement in feeding enables badly infested sheep to throw off many of their internal worm-parasites.

What of the animal life of the moorland? There are a few mammals to be seen now and then—such as red deer, fox, and stoat; some characteristic birds, like curlew and grouse; occasional reptiles and amphibians, such as adder and slow-worm, toad and newt; but the list of Vertebrates is a short one. The Invertebrates, or backboneless animals, on the other hand, are legion. There is a silent bustle among the heather! There is an abundant representation of small snails, some creeping on the dry heather and eagerly picked off by birds like the wheatear; others in moist places, like *Limnaea truncatula*, which harbours the juvenile stages of the liver-fluke. There are numerous spiders, still more numerous insects (butterflies, moths, bees, ants, beetles, midges, dragon-flies, and so on), and many small crustaceans in the pools. There are abundant wheel animalcules and water-bears among the bog-moss, and indefatigable water-mites in the little tarns. Many simple worms, below the level of earthworms, live in the poor soil of the moor and in its water pools; and about fourscore unicellular animals are well known. It must be kept in mind that the heather makes excellent cover for a multitude of small creatures, which live a half-hidden life in its shelter. Sir Arthur Shipley once centrifuged some water with heather steeping in it, and showed what a multitude of very small deer it concealed; and if we sit down among the heather and watch patiently, we get a glimpse of many different kinds of rather larger creatures, such as spiders. Of some we are likely to get very much more than a glimpse.

Drama of the Hedgerow

The exposed moorland, e.g. in the north of Scotland, gives us a glimpse of the Arctic tundra; some sand-dunes, which have been known to smother a seashore farm, are suggestive of the true desert; and an old-fashioned, ill-kept hedge bordering an English lane is

often a miniature jungle. That is to say, it is a crowded plant-association, so tangled that it is difficult to penetrate. It affords refuge to a large number of animals of high and low degree, with the advantage over a true jungle that it offers not only safe shelter, but easy egress into the open. Under its curtain many a drama is being played, and many eyes are upon us as we walk along the road. Can we not turn our eyes on *them*—these furtive wild creatures of the hedgerow?

Little wonder that Darwin was given to scrutinizing the hedgerow! For it illustrates, like a long-drawn-out jungle, one of the most primitive forms of the struggle for existence—the struggle for foothold, for air, for a place in the sun. There are ramping, scrambling plants helped by their hooks, like brambles and goose-grass or Jack-run-the-hedge. There are coiling plants or twiners, like the convolvulus with its beautiful chalice-like flowers. Occasionally there is a stray ivy climbing on a crab tree in the hedge, climbing by its adhesive aërial roots which grow out of the stem.

The bittersweet, a wild cousin of the potato, has developed the art of *leaning*, but it sometimes exerts itself to twine. Highest of all are the tendril-bearers, of exquisite tactility and with the device of forming spiral coils, which draw them close to their support and also serve as anchors with springs. The bryony is a fine example of a tendril-bearer, and so is the clematis or traveller's joy. Less rampant, but very effective, is the common blue vetch. The important fact is that the hedgerow is a haunt where various kinds of climbing plants do well, and it is interesting to see the same result reached by very different adaptations.

Another characteristic of some hedgerow plants is the extent to which the leaves are cut up, so that they expose a large surface to the air and the sunlight, both of which tend to be reduced below the amount that is available in more open places. Thus at the roots of the hedge there is often a vigorous growth of milfoil, in which a single leaf is so 'dissected' that it is like a thousand. Another tendency to surface increase is illustrated in the development of elongated grass-like leaves, as in some vetchlings.

Very typical of the hedgerow undergrowth is the little reddish bank-vole, inclined to sheltered places because of the kestrels by day and the owls by night. A voracious rodent, even climbing the hedge for berries, but lively, dainty, devotedly maternal, and always ready for a shindy. It lives a life of constant danger, always liable to be pounced on, yet with no sign of being so unhappy as is supposed by sentimentalists, who rarely observe. The bank-vole may serve as a type of other little people, like the shrews and the long-tailed field-mouse, which also find shelter in the rank undergrowth of the hedge.

No hedgerow animal can be large, but the hedgehog is a giant compared with the vole. Yet it is a timid giant, not intellectually brilliant, without much of a bite, rather slow on its feet; and so we are prepared to find it a bundle of life-saving adaptations. Most of its hairs are turned into sharp erectile spines; it can roll itself up into an invulnerable ball; it is nocturnal in its hunting; it can sleep through the winter; it is immune to the poison of the adder.

Into the safety of the thick undergrowth we sometimes see a blind-worm or slow-worm disappearing. It is another shy, old-fashioned, elusive creature, in reality a limbless lizard, entirely harmless. Its safety lies in its rapid self-effacement; it is neither slow nor blind. 'It glides smoothly and swiftly in and out between the stems, disappearing at once in a quite mysterious manner.'

The poet's description of the hedgerow shrieking with blood is not borne out by sober observation. Though we must be quite frank about the hedgerow struggle—its diverse thrust and parry—we do not read the drama as mostly tragedy. But we must not ignore the successful predatory creatures of this particular haunt of life, and there could be no better example than the red-backed shrike or butcher-bird, which hawks along the hedge, and impales its booty—mice, lizards, small birds, and large insects—on the thorns, so that it may extract the titbits at leisure. It takes many different kinds of animals to make a world.

One of the best books on hedgerow life is Miss Frances Pitt's *Wild Creatures of Garden and Hedgerow* (2nd ed., 1928).

Wonders of the Roadside

Human progress is always chequered, yet in certain respects it may continue *steadily* for long periods. This is true in regard to civilized man's appreciation of the almost universal interest and beauty of Animate Nature. In spite of the lesson that St. Peter learned on the house-top at Joppa, that nothing natural can be called common or unclean, the idea of everyday things being wonderful and romantic is relatively modern. Part of the modern progress has been due to the influence of Ruskin, whose sense of beauty was so keen; part has been due to man's increasing emancipation from tradition—more people coming to have minds of their own; and part has been due to the growing respect that is being paid to the wisdom of the poets and the insight of the painters.

Surely a wonder is simply any object or process a knowledge of which makes all other things seem finer and more significant; and the modern step is a passage from wondermongering with the strange and exotic to recognizing the wonder that crowds us all our life and

at our doors. As Walt Whitman said: 'The leaf of grass is no less than the journeywork of the stars; and the pismire is equally perfect, and the grain of sand, and the egg of the wren.' As George Meredith put it: 'You of any well that springs May unfold the heaven of things.' In this mood let us walk a mile together along the road.

Common in early summer are little masses of foam on the herbs and grasses by the wayside. 'Cuckoo-spit' they are called, for they begin to appear when the cuckoo calls. A young frog-hopper, such as *Aphrophora spumaria* (the foamy froth-bearer), still in its wingless phase, punctures with its four mouth-needles the skin of the juicy plant, and soon overflows with sugary sap. You can see it moving the hind part of its body up and down many times, as it mixes four things together—air and sugary sap, wax and a little digestive ferment—forming a kind of soap within shelter of which it survives the heat of the day and escapes from hungry eyes. After a while it takes to wing, having saved its life by blowing soap-bubbles.

There is nothing pleasant in the sight of that wild rose bush which is badly infested with *Aphides* or plant-lice, battening on the plant's juices. Yet they have their romance, these little insects, for they are without males all the summer through, and they viviparously bring forth young ones like themselves during a rapid succession of parthenogenetic generations.

Inside the food-canal there is a bevy of partner-microbes, rather like yeast plants, which are able to ferment the sweet sap. Some of the symbionts pass from the mother's food-canal into the egg-cells before development begins; and as the young aphid grows, its internal partners multiply. This is an internal mutually beneficial partnership between two living creatures of entirely different kinds; and such a linkage of lives is called **symbiosis** (q.v.).

In late summer various small spiders are obeying their obligatory urge to climb, and are ascending tall herbs like ragwort, from which they get a good starting-point on their wingless aërial journeys. Borne by the breeze, which grips the long silken threads they spin, they may pass from a crowded to a less crowded area, and even across broad rivers and lakes. There is more than a touch of romance in the successful ballooning of these characteristically terrestrial animals, though sometimes, no doubt, it leads to their being blown out to sea.

On some broad leaves by the wayside we see strange hieroglyphs, which used to be regarded as the signatures of evil spirits. They mark the burrows made by leaf-miners, who eat their way in the soft tissue without breaking the skin above or below—very skilful two-dimensionalism. A leaf-miner is usually the larva of a small moth, sometimes of a two-winged fly or of a saw-fly. They feed on the proteins of the leaf; they dispose tidily and often hygienically of their

refuse or 'frass'; they make characteristic patterns, each after its kind. For it is true of every good species that it is itself and no other through and through, in action as well as in structure.

There in a shallow wayside pool, the overflow of a streamlet, we found once again some writhing horsehair threadworms, which go by the names of *Mermis* and *Gordius*. Each is like a hair from the tail of a black horse, and we once lifted a handful from one little pool. They spend their youthful life as parasites in various kinds of insects, such as grasshoppers; and emerge, when mature, into damp places or pools, there to multiply and die.

Some kinds of blue butterflies, which are among the most fascinating of living jewels, have a strange life-history. The eggs are laid about the flowers of the wild thyme, and the tiny caterpillars that hatch out are very inconspicuous among the blossoms on which they feed. After several moults, the caterpillars become full-grown, and go a-roving restlessly. Some of them fall in with ants, which lick off an elixir that is secreted from a gland on the caterpillar's back. The ants are so fond of this secretion that they insist on taking the caterpillars home with them; and in the ants' nest the caterpillars remain for the winter. Perhaps the ants lick them now and again, but who can tell what goes on underneath the ground? It seems that the caterpillars eat some of the ant-grubs, but there are plenty of these and to spare.

Early in the following year the caterpillars become restless again, leave their winter quarters, and find on a bank where the wild thyme grows a suitable place for pupation, that is, for undergoing the great change or metamorphosis into butterflies. The blue butterflies emerge and flit about in the sunshine, caring more for love than hunger. After a time the females lay eggs on the flower-heads of the thyme, and the story begins again. Such is just a glimpse of the romance of the roadside.

CHAPTER III

LIFE AND THE SEASONS

The march of the seasons—Biology of spring—Spring coming in—Lambs and sheep—May blossom—The floral pageant of July—Summer butterflies—The fall of the year—The cleansers of the earth—Wintering—Butterflies in winter—How flies pass the winter—A pond in winter—A biological walk in winter—Winter visitors—Winter waiting.

IN discussing the haunts of life we have been thinking of the *spatial* relations of organisms; we must turn now to *temporal* relations, and to the march of the seasons in particular. No small part of ecology (or Natural History) has to do with the way in which plants and animals respond to the great external periodicities—day and night, high tide and low tide, summer and winter, though these are experienced very unequally in different haunts. The great abysses of the ocean illustrate eternal night, relieved only by the fitful gleams of luminescent animals; the Mediterranean is a tideless sea; the equatorial forest, such as that pictured by Mr. Beebe in British Guiana, is almost seasonless. But these are exceptions; well-marked periodicity is the rule. Let us illustrate the reactions of plants and animals to the march of the seasons.

THE MARCH OF THE SEASONS.—One of the large facts of life is the way in which living creatures tend to fill up every corner of earth and sea. Thus there are many plants and animals in the barren grounds or Arctic tundra, snow-covered and frost-bound for eight or nine months of the year; there is a very distinct fauna and flora of the high Alps, where snow-voles and blue gentians are at home; there is a dense population of animals in the unbroken night and endless winter of the Deep Sea. But another great fact of life—the subject of what is often called phenology—is the waxing and waning of life as the earth moves round the sun. In other words, there is a march of the seasons, especially well marked in temperate countries, and the seasons do to some extent hold living creatures in their grasp.

Since the sun is the source of almost all the energies of the earth, our income—of heat and light in particular—varies with our seasonal position in relation to the centre of our system. With this chief relation of temperature and illumination there are associated many minor seasonal variations, as in rainfall and winds; and the waxing

and waning in the physical world sways in great measure changeful aspects of life in plants and animals. The basal fact is that the ratio of heat-supply in summer to that in winter is as 63 to 37.

Beginning with spring, we see it as the season of renewed activity and strength. The water in the soil begins to move again, and there is a quickening of the cycle of mist and cloud and rain. Into the quiescent seeds the water begins to soak, sharing in the ferment that is going on; the seeds sprout, the seedlings lift their heads above ground, the brown earth becomes green. The water rises to the tops of the tall trees, and the buds that were formed in the warmth of last summer's sunshine begin to grow and swell and open, scattering the protective bud-scales on the ground. Almost everywhere over the earth there is stretched a green veil which enables the plants to capture part of the power of the sunshine. Spring is a time of fresh life, of reinvigoration, of becoming young again.

Fig. 307. Dormouse

The 'winter-sleepers,' like hedgehog and dormouse, come out of their retreats, with a new lease of life after their long rest. Spring is a time of reawakening. The migratory birds, like swallow and swift, cuckoo and nightingale, begin to return from their winter quarters in the south, and some of them are no sooner here than they begin to sing songs of love. For spring is a time of love-making. Naturally enough it is also a time of young things, for eggs are laid and new creatures are born. Who can think of spring without picturing caterpillars and tadpoles, nestlings and lambs? The ponds and the shore pools which seemed so empty in winter begin to teem with what we may, with Charles Kingsley, call 'water-babies.' After a long journey of two and a half years or more, the young eels or elvers, hatched out

in the distant Atlantic, make their way up the European rivers. The larvae of the American eel, whose breeding-ground overlaps that of the European species, has a shorter journey and arrives in the rivers when about a year old. What with births and immigrations, spring is a season of re-peopling both in the waters and on land. A great deal depends on the multiplying of minute green plants in lake and river and sea, for these form the basal food-supply of aquatic animals, just as the multiplication of the blades of grass, in the wide sense, is the most important event on land. The circulation of matter from one embodiment to another is slowed down in the winter, but it is quickened again in spring. Grass begins again to become flesh, and one reincarnation follows another all the world over.

Summer means a great increase of income and therefore the possibility of a great increase in expenditure. The day is longer and warmer, and what may be called the industry of green plants is incalculably great. Every sunlit green leaf is making carbohydrates and proteins, and great quantities begin to be stored in root-stock and tuber, corm and bulb, to give the plant capital to start with next spring. But as leafing is characteristic of spring, so is flowering of summer. No doubt there are many beautiful spring flowers, mostly white and yellow, like snowdrops and celandine, but it is in summer that the crowded floral pageant begins to move, and its colours seem to heighten as the months pass. It is in summer that we see so much of the most important linkage in the world, that between flowers and their insect-visitors. 'Most important' because many of these visitors, notably the bees that come for nectar and pollen, carry the fertilizing golden dust from one blossom to another blossom of the same kind. It is this fertilizing pollen that makes the possible seeds or ovules into real seeds that will sprout; in other words, the nucleus of the down-growing pollen-tube fertilizes the egg-cell within the ovule within the ovary or seed-box of the flower. Sometimes, as in the pea, there is self-fertilization; but cross-fertilization is much commoner. Sometimes, as in fir trees and grasses, the wind carries the pollen; but pollination by insects is far commoner. In some warm countries, like Java, honey-sucking birds play an important part in the distribution of pollen.

In spring one sees many examples of animal play, for instance among lambs and kids and calves, and this is often continued into summer. But the larger fact is that spring play is succeeded by summer work. Or, to put it more accurately, since play is restricted to the higher reaches of the animal kingdom, summer is characterized by industry. In spring, both among plants and animals, there is much living on the strength of the past; in summer there is living on the present for the present, and for the future. What studies in

animal industry we see in the summer months! Just as in mankind, there are hunters and fishers; there are miners like moles and foresters like beavers; there are agricultural ants and others that keep domestic animals. But the climax of summer industry is to be seen in the ant-hill, the termitary, and the beehive. Perhaps the most beautiful form of wealth, that is to say stored energy, in the world is the honey in the honeycomb. It is collected, at least half-unconsciously, because it enables the bees to survive in the winter months when there are no flowers to visit, but man robs the store. Man has therefore good reason to applaud the busy bee, but no naturalist can look at the hive without remembering that there is a seamy side to the extraordinary industry. These children of instinct, in thrall to social arrangements that have become too strong for them, rapidly become victims to nerve fatigue. The life of a worker summer bee does not usually last for more than a month or six weeks. There is a risk in being too energetic in the summer season!

Autumn marks the turn of the tide that began to flow in spring and reached high-water mark in summer. The days become shorter and colder. Spring for foliage, summer for flowers, autumn for fruiting; and the meaning of the fruit is to secure the dispersal of the seeds—the sowing of the next generation. In some cases the nectaries of the flowers close and the surplus sugar is drafted into the fruits, making them tempting to birds. It may seem a bad beginning to be swallowed by a bird, but the seeds are in such cases usually very hard and pass down the bird's food-canal not a bit the worse. Other fruits like those of goose-grass (Jack-run-the-hedge) and burdock catch on to passing animals and get rubbed off far away. Others, again, like thistle-down and dandelion-down, are minute nutlets with a parachute of silken hairs which the wind wafts hither and thither till some of them at least are caught on a suitable place. But many fruits are simply dry pods or boxes which die and crackle and split, liberating the seeds sometimes forcefully. We must think of autumn as a time of seed-scattering.

Very characteristic of autumn is the withering and the fall of the leaves. They have worked hard all the summer, but they would be sources of weakness in winter when soil-water is less available and when freezing of delicate tissues is apt to occur. So the leaves, transfigured in dying, are shed in the autumn, which is often appropriately called 'the fall.' It is interesting to find that before they are separated off by a partition which heals the wound, they surrender to the stem almost all that is worth having. The fallen leaves which the earthworms bury contain little more than dead tissue and waste-products.

What the trees do in surrendering vulnerable parts is also seen

among animals. Thus many of the plant-like zoöphytes in the shore pools 'die down' in the autumn, reminding one of herbaceous plants. The green freshwater sponge dies away in autumn, all but little pin-head clusters of cells called gemmules, which eventually float away from the dead skeleton and start new sponges in spring. The sacrifice of parts or members finds expression in some of the social insects in a striking way, for of the wasp colony and the humble-bee family only the young queens are left to face the winter. In the beehive there is an eerie cold-shouldering and final killing of the drones in autumn. No doubt autumn must be thought of as a time of retrenchment. One of the common autumnal sights is the flight of gossamer spiders, which are scattered by the wind as if they were seeds. When the silken threads, often four in number for each aëronaut, sink to the ground in thousands, we see a 'shower of gossamer,' often a very beautiful sight. The scattering is of value in enabling the spiders to shift from a crowded to a less crowded haunt, and it is a fine instance of the way in which animals attempt the next to the impossible and achieve it. For who would expect thoroughly terrestrial animals, without wings, to make successful journeys through the air? Gossamer flights are not restricted to autumn, but they are commonest at this season; and it must be recognized that there is no hard-and-fast limitation of particular kinds of activity to particular times of year. Thus summer is the season of greatest animal industry, but earthworms are busiest in autumn. There are more leaves to work with, and the formation of vegetable mould goes on rapidly in all suitable places. The leaves that the earthworms drag into their burrows are partly used for food, but many of them simply rot away, so that the fertile soil often gets better and better year after year.

Winter is a difficult time for many plants and animals in north temperate countries. It is a yearly reminiscence of the Ice Ages which have occurred repeatedly in the history of the earth and have from time to time severely pruned the growth of life. Short days, low temperature, stormy weather, scarcity of food—these are sharp pruning-hooks. The problem is to keep alive, and there are many solutions. Neatest of all is the migration solution, for the birds that come as summer visitors to north temperate countries take their departure in late summer or autumn for more genial climes. Thus they know no winter in their year; they have not only annihilated distance, they have circumvented the seasons. Very different is the hibernation solution exhibited by some imperfectly warm-blooded animals, like the bats, which seek out secluded nooks, where the temperature rises above that outside, and sink into a strange, almost reptile-like state. Out of their weakness in being imperfectly warm-blooded, that is to say, unable to adjust their production of heat to

their loss, they make a strength, for hibernation works well. There they lie or in the case of bats, hang, in safety, through the cold and storm. They eat nothing; they excrete nothing; their heart beats feebly; the breathing movements are scarce perceptible—but they survive. The word 'hibernation' should be restricted to a few mammals, but a somewhat similar 'lying low and saying nothing' is seen in the coma or lethargy of many lower animals, like some frogs and fishes, like many snails and insects. In many cases the insect lies quiet through the winter not as an adult but in its pupa stage, well wrapped up in some cocoon; in Europe most of the butterflies pass the winter as caterpillars well hidden away.

Another kind of solution is to fall back on stores, sometimes inside the body in the form of fat and other reserves, often outside the body in the form of caches of food. The squirrel stores nuts, the beaver pieces of branches, the hamster hay, the bees honey, the ants grain—and it is easy to multiply this list by ten. Besides those we have mentioned, there are many other solutions of the winter problem. Thus it is of some advantage to the chestnut-coloured stoat that it becomes in winter a snow-white ermine, all but the black tip of the tail, for in a very cold place a dress of white fur keeps in the precious animal heat better than a coat of any other colour. Perhaps the blanching, which is familiar also in the variable hare and the ptarmigan, gives the creature a useful cloak of invisibility. Wolves live alone in the summer, but as every one knows, they form packs in winter, which seems to make hunting easier. We need not continue, however, for the point is simple: that while winter is on the whole a hard time, with a stern struggle for existence and great mortality, living creatures face up to the difficulties with wonderful success. Thus a season of severe sifting and much dying must also be thought of as a resting time and as a preparation for another spring.

Illustrations of Seasonal Activity

BIOLOGY OF SPRING.—April is the month of opening—of the earth, of the seeds, of the buds, of the early flowers, of the eggs, and of the womb. The migrant birds return, sometimes to the farm where they were born the year before. The humble-bees appear from their winter's rest in the mossy bank—the only survivors of last year's community; the hedgehog has long since reawakened from its hibernation. All the corners of the earth and of the waters under the earth are beginning to be full of young things—each often a fresh start in evolution, that is to say, with some new departure that may be of value. The sap ascends from the stores in the tree, and from the thirsty roots in their soil solution. From the wound on the birch

we see it overflowing. Spring is the time of awakening on the part of many living creatures that have been resting through the winter in diverse ways—as seeds, as cocoons, as bulbs, as tubers, as buds, as adults. But it is also the time of marrying, pairing, and mating—the beginning of altogether new lives.

SPRING COMING IN.—One fancies that the word 'spring', as a name for the ' vernal season,' suggests a bound out of captivity into freedom. This aspect is very characteristic of spring in the far north, where the emancipation from the tyranny of winter comes suddenly. The temperature rises above a certain point, and the prison doors are flung open. There is a breaking-up of the ice on the rivers, a melting of the snow into floods, a restoring of the stopped circulation of water in that meteorological cycle of mist, clouds, rain, streamlets, rivers, lakes, and seas, which is so essential to life, since every plant and animal is a water eddy. One must never forget that living matter or protoplasm normally contains 70–80 per cent of water. So there was the usual grain of truth in the exaggeration of the materialist who declared that life was fundamentally a problem of hydrodynamics. Perhaps he would have been nearer the truth if he had said psychodynamics, though that may be an instance of the hazardous device of trying to speak two languages at once.

The above was an aside; for our aim was to emphasize the frequent abruptness of the northern spring. In a few days vast areas of the barren grounds or tundra become floral; the sub-Arctic desert, with its well-sheltered vital reserves in bulbs and corms and rhizomes, blossoms as the rose; the empty air is suddenly filled with clouds of mosquitoes and midges; and the return of the migrant birds from their southern winter quarters makes the waste places vociferous. The sudden incoming of spring in the far north is a well-known fact of Ecology, or as we prefer to say, Natural History. Spring comes in more gradually in southern countries; even in the south of England its coming is often like a dawn. In Scotland its advent is more hesitating; there are checks in its forward march; the seeds sprout and then become discouraged; the buds begin to open, and they are often nipped. Organisms in the north have learned to be cautious; and yet when there is a sudden rise of temperature, much more noticeable to some organisms than it is to man, there may be an illustration of the characteristically northern bound. After a long cold winter, with little sunshine, there comes a sudden increase of heat and light, and there follows a bound of life, which, rightly or wrongly, we think of as a characteristic feature of spring. In some places at least it seems to us as if there were a sudden breaking of a spell. There is an abrupt emancipation of life. With a dramatic gesture the sun throws open the prison doors.

In temperate countries there is not, indeed, any all-round suddenness in spring, for it comes in instalments as usual; nevertheless, in certain places and in regard to certain organisms it has come with unusual abruptness. One day in the very centre of Scotland a well-grown pussy-willow tree was little more than a study in bare boughs; we passed two or three days afterwards and it was profusely decorated with pale golden catkins, glittering in the sunshine. These catkins are bunches of male flowers reduced to a minimum, little more than fluffy groups of stamens; but what an exuberant and abrupt outburst of masculinity! There was no female tree, with pistillate flowers, near at hand to be pollinated, but it does not follow that the male tree wasted its pollen on the desert air. For the humble-bees visit the willows and carry the golden dust from tree to tree. In this respect willows differ from birches and alders, which also bear catkins, for these are wind-pollinated.

It was of set purpose that we spoke of an outburst of masculinity in the male willow tree, though we are well aware that the botanist is accurate who insists that flowering plants are really spore-producers or sporophytes. But, when all is said, the stamens produce pollen grains which give rise to the fertilizing male elements, and the pistil contains ovules, which give rise to egg-cells. When the egg-cell is fertilized it develops into an embryo plant, and we call the fertilized ovule a seed.

One spring in Aberdeenshire, on a stretch of marshy ground there was nothing particular doing on the Friday, but on the Saturday the marsh was alive with frogs—five hundred within a short radius! The scene was arresting—an orgy of sex-urge, amphibian saturnalia. As the Bible says, 'There is a time to embrace,' and the male frogs seemed to be possessed with a sex-fury, which is well known to be associated with the liberation of a reproductive hormone or chemical messenger into the cold-blooded creature's circulation. When many living creatures of about the same age and in the same physiological state are simultaneously activated by some sudden change in the environment, then we may expect to see the bound of spring, *natura saltatrix*.

One of the grandest views in Scotland is from the crest of the Cosheville road from Kenmore to Tummel Bridge, where one stands in the midst of an amphitheatre of mountains. One day in early spring their loftier features were still picked out in snow, while on their lower slopes the heather was burning. As we lingered there on our spring holiday we felt as ever the truth of Schiller's words: *O wunderschön ist Gottes Erde, und schön auf ihr ein Mensch zu sein* (How wonderfully beautiful is God's earth, how fine a thing it is to live a man's life in its midst).

It was still wintry, and it was not altogether easy to believe that spring was coming in. Yet as we listened we heard the notes of Pan's pipes faintly in the distance, and for the rest of our week we heard little else. One note was colour, the reddening of the stems of the bog-myrtle, the tassels of emeralds from the larch branches, a group of young poplars like candelabra of golden light, the brightening of the red wattle on the head of the blackcock, and a cock yellow-hammer who looked ever so proud of himself on the top of a wall.

Another note was lyrical, the trilling, courting call of the curlew or whaup, the plaintive cries of the lapwing, the cheerful melody of some of our resident songsters, and, as a discord emphasizing the music, the cacophonous 'go-back, go-back' of the grouse.

Another note was youth—the playful lambs and some still too wobbly to play, the young rooks in their high cradles on whom the apparently proud parents were gurgling tenderness, the young salmon fry in the river, and the first cloud of midges we had seen that year. But it is a hopeless task to catch the notes of Pan's pipes—they are so many and varied: the crocus breaking through the sod, the fragrance of the pines, the moan of passionate doves, the bending and bowing of the seedlings, and all the overture of April.

LAMBS AND SHEEP.—When we watch lambs in the springtime, three thoughts always rise in our mind. The first concerns the maternal instinct which is so strong and yet so deeply automatized in many animals. The ewe is solicitous, patient, tolerant, and devoted, yet is it not the case that a gimmer (young ewe) is sometimes frightened of her own new-born offspring, and will not mother it unless it be held to her mouth and nostrils, when the taste and smell pull the trigger of the strong instinct? Is it not the case that the taste of the amniotic fluid of another ewe's new-born offspring will induce 'lamb-theft' on the part of a ewe that has not yet lambed, and that this may be fatal to the welfare of her own progeny? Of course we are observing domesticated animals, but we cannot but be impressed with the heavy price that animals have often to pay for instinctive automatization.

Our second thought concerns **the biological value of play.** For (1) it is the safety-valve for overflowing spirits and motor energy; (2) it is a not too serious apprenticeship to the business of adult life, and thus the lamb's games are very different from the kitten's; (3) it is an opportunity for the expression and for the testing of variations or new departures in behaviour, before the criticism of more responsible life becomes too severe; and (4) it is for gregarious and social animals, and pre-eminently for man, a discipline in that give-and-take on which the success of communal life so largely depends.

Animals do not merely play because they are young; they remain young in order that they may play.

The third thought concerns the change from the lively, adventurous, experimental lamb to the stolid, respectable, acquiescent, domesticated sheep. This change is much less marked in the wild sheep, so we suspect that man is to blame. He makes the sheep too comfortable, too safe, all too thoroughly bereft of responsibilities. Therefore it suffers individual degeneration of mind, just as a hen usually does. Moreover, for a long time he has been eliminating rebellious, original, and independent sheep, so that the race sinks into docility after a short youthful reminiscence of the old freedom and adventure. This is part of the price of mutton!

MAY BLOSSOM.—As children are good-humouredly surprised at the fiftieth repetition of a parental sleight of hand, so are we with the transformation scene when the sloe bushes burst into blossom, or when the hawthorn tree turns into cascades of flowers. The sloe or blackthorn seemed all unpromising in its stark nakedness, without a leaf showing, with only inconspicuous buds; a wave of the wand and it is covered with white stars, every twig a constellation. The hawthorn or whitethorn was leafy enough, but what stranger could have predicted the foaming exuberance? And there are so many other instances—the burning bushes of gorse and broom, the thousand candelabra of the horse-chestnut, and the wonderful white curtains spread out on the wild cherry.

We know, of course, that there is no need for surprise, yet we have a sort of catch in our breath every time, and we wonder if the emotion is not as wholesome as botany. Wordsworth no doubt knew that, given the rays of light and the water-droplets, the rainbow had to be there, yet his heart 'leaped up'—the bodily reflex of his emotion. Prism or no prism, the rainbow is beautiful; that is to say, it excites in us a distinctive kind of emotion, revealing a certain correspondence between the heart of things and what is best in ourselves. It also lifts the corner of a mystery, and it has become a symbol. So it is with the may blossom, and we are unfeignedly glad that it is so. It is a perennial surprise; it is surpassingly beautiful; it seems to lift a corner of the curtain of the fundamental mysteriousness of life; and it has become a symbol of the gladsomeness of summer.

This exuberance of foliage and flower we know to be a liberation of buds that were formed in the abundance of last summer and have lain latent through the cold months. Sunshine and sap are the two keys which open the prison doors of the bud-scales and let the leafy shoots and implicit flowers grow and differentiate and expand. The botanists are beginning to tell us that much of the watery sap which makes the first growth possible in spring is stored throughout the

winter in the heart of the tree, and does not require, to begin with, to be brought up from the roots. What we must be clear about is the elementary proposition that the spring showers and spring sunshine are not more than the liberating stimuli of buds which were formed long ago. In a deep sense the flowers of 1934 were the reincarnation of the foliage of 1933. For so the world goes round.

The second scientific light that is thrown on the may blossom comes from a recognition of the fundamental antithesis between leafing and flowering, between nutrition and reproduction, between self-increase and the giving origin to new lives. This is one of the see-saws of life. Every one knows the close analogies between a foliage shoot and the flower, and there was essential correctness in the view of Goethe and others that the flower is a cluster of transformed leaves. We have to add that two of these transformed leaf-structures—the stamens and the carpels—bear organs of propagation or sporangia; but Ruskin, though he boggled badly over it to start with, was not far wrong in the end when he said: 'And when the leaves marry they put on wedding robes, and are more glorious than Solomon in all his glory, and they have feasts of honey, and we call them *flowers*.'

The climax of the vegetative life is seen in the vast acreage of green in the trees of the forest, in the abundant photosynthesis (q.v.) which goes on in these laboratories (some of the energy of the sunlight being used to build up carbon-compounds), and in the growth and the storage which this makes possible. But periodically the vegetative life is interrupted by the production of flowers—the antithetic reproductive life; and one of the fascinations of biological study is to trace the see-saw between the two. Sometimes, as in a moonwort fern, we see the vegetative industry on one branch and the spore-making on another; sometimes, as in the American aloe, we see the vegetative life continuing year after year, perhaps for seven or more, and then suddenly there rises the lofty flower-stalk, with, it may be, 4,000 blossoms. When these have fruited the plant dies down to the ground. The fact that the reproductive activity in plants is split into a spore-bearing and a sex-cell-bearing generation, and that the former has practically swallowed up the latter in flowering plants, is not essential to our present argument, which is simply that the exuberance of may blossom illustrates the see-saw between vegetative and reproductive activities. It is interesting to remember how in some animals the two great concerns of the organism, 'hunger' and 'love,' if we use the terms widely, are separated into distinct periods—the caterpillar feeding and growing, the butterfly often fasting but reproducing. Or they may be separated into different generations, as in the vegetative asexual zoöphyte and the reproductive swimming-bell to which it gives origin.

A third gleam of light comes when we inquire more deeply into the significance of the flower. Stamens and carpels bear sporangia (the pollen-sacs and the ovules) which produce spores (the pollen grains and embryo-sacs respectively) but a flower is more than a couple of whorls of appendages bearing sporangia. In the first place, with the establishment of land plants there began a gradual predominance of the spore-bearing generation (which we see as a distinct plant in an ordinary fern), and a gradual recession of the sex-cell-bearing generation (which we see as a distinct plant in the prothallus of the fern); and in flowering plants the latter has become a mere vestige. Wrapped up with this is the fact that the fertilized egg-cell of the flowering plant is retained within its parent, which in turn has ceased to be separate from the neutral spore-bearing individual (see ALTERNATION OF GENERATIONS).

The net result of a very intricate evolution is that the young plant is kept for a long time within its parent (and grandparent), nourished and protected before its separation as a ripe seed. This brings the flowering plant into an interesting parallelism with the viviparous mammalian mother, though the latter is not known to show any trace of alternation of generations. The important fact is that the vegetative vigour of the hawthorn tree equips the seeds and the fruits.

A fourth contribution to an understanding of may blossom comes when we consider the accessories of the flower as converging to an unconscious end—the continuance of the race. The sepals of the rose-like flower steady the whole and help to form the fleshy 'berry.' The red pigment and the palatability of this fruit ensure the visits of birds, who digest the soft part of the 'haws' and scatter the undigested seed. Previous to this, of course, came the small insect-visitors who carried the pollen grains from the stamens of one flower to the carpels of another and secured cross-pollination. To them there is probably attractiveness in the fine whiteness of the petals, due to the almost perfect reflection of the light from the surfaces of numerous gas-bubbles in the cells. For the whiteness of the may is very literally a living foam. There is a second attractiveness, namely the characteristic fragrance, which is due mainly to the compound called trimethylamine, probably in the first instance a waste-product in the internal economy of the hawthorn. Best of all, perhaps, there is the nectar, which the flower owes to the sugar which the leaves have made. The visitors are small flies, bees, and beetles, and the best time for calling is in bright sunshine, when the stamens bend outwards and expose the ring-like nectary. In dull weather the stamens bend inwards on the carpels, which always ripen first, and in this way self-pollination is readily effected.

It seems, then, that may blossom has its depths as well as its

heights; and yet, as science goes, we have not gone very deep. But our conviction is that the more we understand, the more beautiful the may blossom becomes. At times, indeed, the dryad revisits the tree.

Summer

THE FLORAL PAGEANT OF JULY.—The majority of conspicuous yellow flowers belong to spring and the struggles of early summer; and in most places the glory of the gorse and broom is past by mid-summer, and the laburnum's 'dropping wells of fire' are long since dry. Yet there are many yellow flowers in summer, one of the largest being the yellow flag or iris, and it is a joyous sight when a stretch of them is near enough to water to be mirrored. There seems to have been a great diffusion of the yellow mimulus of recent years, as an escape from cottage gardens. In many a ditch it is continuing for a hundred yards the succession of the marsh marigold. The moor is often glowing with yellow tormentil, and in a shaded place in a wood one may find the yellow pimpernel, a delicate cousin of the primrose. In the wayside ditches there is a great abundance of the spearwort, a buttercup with somewhat grassy leaves, and in some woods there is a stately aristocrat, the leopard's bane, rising two feet above the ground. Everywhere on the golf-links, beyond the close-cut fairway, there are gorgeous clumps of golden crowfoot, flecked with red in the bud. No need to speak of hawkweeds and ragworts, for they are among the yellows of many months.

Finest of all, perhaps, in the quality of its gold, is the rock-rose, like a glorified silver-weed or *Potentilla*, though not a near relative. It likes dry places and clean, loose soil; it basks in the sun, closing on dull days. Like the musk, with its sensitive, mobile stigma that shuts on the fertilizing pollen, so the rock-rose has irritable and mobile stamens, which answer back to the insect-visitor or even to the tip of one's little finger. These are two common instances of the way in which the plant may betray the fact that it has something of the animal lurking within it, and is by no means asleep.

We cannot, of course, be enthusiastic over the multitudinous yellow charlock that is such a harmful weed in many fields. But it should be noted that this eyesore—suggestive of a flaunting advertisement of mustard—is possible only because of agriculture, just as certain tree pests are possible only because of the unnatural density of plantations. It is part of the farmer's task to put an end to this expensive splash of yellow, a plague, not a pageant, and agricultural science with its differential spraying has now shown how charlock may be balked. That is to say, there are sprays that will kill the charlock without injuring the crops.

White is another primitive colour that contributes to the July pageant. Whiteness means, of course, that there is no floral pigment at all, simply many minute air-containing bubbles between the cells. These serve as so many tiny mirrors reflecting the light in its entirety, and then we say 'white.' Many stretches on the moor look like crowded encampments with white tents. These are the fields of cotton-grass with their delicate silvery-white flags waving in the wind. Some have threads over two inches long. It seems a pity that man cannot put this cotton-grass to some use. Picture the joys of such wool-gathering! Another impressive white field is a great stretch of bog-bean extending over the shallows of a lochan, with the almost exotic spikes rising high above the surface of the water. Very characteristic of July and making the air fragrant is the meadow-sweet, and not less graceful is the little white bedstraw on thousands of roadsides. The meadow has only too many moon-daisies or marguerites, with their halo of white and their heart of gold. Finest of all, perhaps, but quickly passing, is the greater stitchwort that spangles the hedgerow with white stars.

Of richer colours, what can we rank above the purple of the fox-glove's familiar spire? With what profusion do these graceful plants spring up where there has been a clearing by the side of a wood, and especially if there has been some burning! They seem to like loose soil and a certain amount of shelter from the wind. In some places they are among the characteristic flowering plants of the railway embankments. The most gorgeous inflorescences this month are probably those of the brilliant red *Tropaeolum*, which we may almost rank with the wild flowers, since in some parts of the country it makes the old-fashioned wayside cottages 'perfectly lovely.'

The colours of flowers deepen as the summer goes on, and it is with August that we associate most of the fine reds, and blues, and purples. Yet some are already with us in July, such as the pink wild-roses, the fine mixture in the honeysuckle, the blazing red poppies amid the growing corn, the delicate pink ragged robin in wet places, the tall willow-herb by the side of the slow-flowing stream. There are not many notable blues besides the unsurpassable germander speedwell and the wondrously beautiful meadow cranesbill; but even subtler is the meadow cranesbill's superb cousin, the crimson-veined *Geranium sanguineum*.

Another way of looking at the pageant of July is to picture the plants of a particular type of country-side. What, for instance, are the half-dozen or so flowering plants that give character to a Perthshire glen in July? Besides the yellow tormentil and the cotton-grass and the white bedstraw already mentioned, we see amid the fragrant bog-myrtle, volatilizing in the welcome warmth, the beautiful golden-

orange spikes of the bog-asphodel. Everywhere among the bog-moss in its varied hues, some as if stained with blood, there is the insectivorous butterwort (*Pinguicula*), with a ground-rosette of five leaves or so, plump and glistening, quaintly suggestive of a starfish ashore. The fine flower is not yet. Not less characteristic is the beautiful blue of the small milkwort, and in pausing to examine its rather difficult flower we are likely enough to find the red sundew, whose carnivorous leaves are more floral than the blossoms. Not to be forgotten are the spotted orchids, sometimes very abundant, and the purplish marshworts which are addicted to root-parasitism. When we make a picture in our mind of cotton-grass and tormentil, bog-myrtle and bog-asphodel, butterwort and sundew, white bedstraw and marshwort, orchid and milkwort, and queen of the meadow ruling over all, we are photographing the July pageant in a Perthshire glen, though only in its more salient features. We must proceed to do the same for the wayside and the hedgerow, the river-side and the moor, the meadow and the links, the woods and the open hill; and when we add them all up and see them in their waxing and waning, we shall be beginning to get a glimpse of the pageant of July.

SUMMER BUTTERFLIES.—For all the seasons we should have symbols, expressive of their true inwardness. Take for spring the primrose and the returning swallow; for autumn the withering leaves and the squirrels hiding beech-mast; for winter the mistletoe and the ermine in its white dress. What should we name for summer, where the embarrassment of choice is greatest? What can be better than roses and butterflies?

It is often, and up to a point rightly, said that the business of life is twofold—caring for self and caring for others. To put it in another way, the major activities of life may be thought of as a see-saw between nutrition and reproduction. One must not, of course, forget all the ancillary functions which make the living creature a going concern, able to persist from day to day, but the major motives are 'hunger' and 'love.' The caterpillar, as we said a little while ago, stands for hunger, the butterfly for love; and the contrast becomes vivid when we remember that caterpillars are quite sexless and that some butterflies never eat at all.

The caterpillar grows rapidly, and has in consequence to moult its cuticle many times—five a common number. But the butterfly does not grow at all, and, of course, it does not moult. We say 'of course' because in the higher insects, with metamorphosis, there is no moult, save once in may-flies, after the winged stage has been reached. Thus butterflies are fit emblems of summer, which is the time of flowers, that is, of reproduction.

The patterns of butterflies' wings are hieroglyphs, for if one studies

them long enough one can write the racial history of *Lepidoptera* from the information they give. The beautiful wings are worked by highly developed muscles, and in various ways the two on each side move as if they were one. This must simplify the flying problem, but the dragon-flies, which are the best fliers among insects, can use the front pair independently of the hind pair. Many quickly flying insects, such as bees, sometimes show 200–300 strokes in a second, but butterflies are leisurely, and the flight depends on gently striking the air with a large surface.

A cabbage-white butterfly can cover about six feet in a second, a swallow-tail about twice as much; but these are very small velocities compared with that of a honey-laden bee making a bee-line for the hive. Yet butterflies sometimes travel in large numbers over great distances, as we know from the swarms of red admirals and painted ladies that sometimes arrive in Britain from the south in early summer.

Since a butterfly is fully formed when it emerges from the chrysalid and does not grow any more, it does not require food except to make good what is expended in locomotion and in egg-making. And for these two functions there are available reserves handed on as a surplus from the caterpillar stage. Thus for many butterflies nutrition is unimportant, and some do not eat at all. Moreover, many are very short-lived.

But while the big fact is that the caterpillar is nutritive and the butterfly reproductive, one often sees butterflies visiting flowers, and some of them, like the red admiral, have a very sweet tooth. A number of flowers, such as pinks, campions, phloxes, and orchids, are visited by butterflies which suck a little nectar and incidentally distribute pollen. But as they do not collect pollen, they are much less important than bees in the cross-fertilization of flowers, moreover they are much less constant in their visits.

Some strange tastes are illustrated among butterflies; thus certain Swiss 'blues' will feed on the drops of perspiration on one's brow. Some suck up the sweet sap exuding from trees, and others settle on fallen plums. But the majority are very dainty feeders—often living on nothing!

Male butterflies are often more brilliantly coloured than their mates, as may be seen in 'blues' and 'orange-tips'; and that this counts for something in courtship is strongly suggested by the fact that in exceptional cases where the female is the more brilliant she is the more active in wooing.

Butterflies have a colour-sense and prefer certain flowers, e.g. reds, to others; and it is probably safe to say that a brilliant dress may help in mating to attract and rivet attention and to excite sex interest and urge.

Often, however, scent counts for much, and the arrangements may

be elaborate. Many male butterflies have scent-patches on their wings, where minute glands produce an odoriferous secretion. This may diffuse into the air, and the scattering is sometimes helped by a microscopic dust formed by the breaking up of chitinous threads. But to the scent-organs on the wings there may be added abdominal brushes, each in a minute eversible bag. The brush is brought into contact with a scent-patch, and then the threads of the brush disintegrate into fragrant dust. Butterflies carry the use of scent to a high pitch of perfection. The pairing is in the air, as every one has noticed; and the more active sex, whichever that may be, carries the other.

But the climax of the butterfly's activity is also in many cases its end, for death follows swiftly as the Nemesis of giving origin to new lives. Thus the dying butterflies of our closing summer are in artistic and scientific harmony with the withering of annual plants. Fixed flowers and winged flowers fade away together. How forcibly one is reminded of Goethe's saying: 'Nature holds a couple of draughts from the cup of love to be fair payment for the pains of a lifetime.'

Autumn

THE FALL OF THE YEAR.—Two aspects in the biology of autumn stand in marked contrast, though logically and organically correlated. On the one hand, there is the ebb of life—retreat, retrenchment, and death itself. On the other hand, there is the prodigal scattering of seeds, for the time of Man's harvest is the season of Nature's sowing. The grass withereth and the flower fadeth—that is the one aspect; the air is full of plumose, parachuting seeds of thistles and ragworts and old-man's-beard—that is the other aspect. Many dead shrews lie about the wayside, for they are short-lived animals; but up many of the rivers the salmon and the sea-trout are pressing against the stream on their reproductive journey, for the eggs are shed in the cold months. The fires of life are burning low, in many cases they go out altogether, for not a few living creatures are annuals. On the other hand, there are hundreds of gossamer spiders ballooning through the air and there are large coveys of partridges among the stubble. How are we to reconcile these two aspects of autumn?

In the first place, just as there is in many creatures an alternation of work and rest, of waste and repair, of upbuilding and downbreaking; just as the life of an actively discharging or unloading gland-cell must be interrupted by periods of charging or loading; just as for the very intelligent highest animals there must be a punctuation of the wide-awake hours with times of sleep: so there is little chance of wholly evading the seasonal rhythm. Autumn is the fall of the year, the ebb-tide of life, the annual curfew, and only a few organisms, like the migratory birds, are able to evade it altogether.

And, besides the internal physiological necessity which compels an alternation of relative rest and repair with relative activity and waste, there is the big external fact that supplies of food and radiant energy are greatly restricted in autumn and winter in northern countries. Life is inherently rhythmic, but it is punctuated by the seasons. Thus we have to think of life as showing a slow see-saw, with a continual tendency for the lower end to dip below the limit of variability. What marks the biology of autumn is a great variety of adaptations by which the fatal nadir is evaded. Thus there is a sacrifice of vulnerable parts, as in the falling leaves; there is a gathering together of the fire of life into underground or well-protected parts; there is the storing of reserves inside and outside of the body; there is a thickening of the coat in many a plant and animal; there is often a sinking down into a state of minimal activity and suspended animation. When the worst comes to the worst, the individual organism has to die, and then the adaptations take the form of securing that the race is continued by resistant germs and seeds, cocoons and chrysalids, gemmules and winter-buds, which lie low through the wintry months of elimination and give the race a fresh start the following spring. Thus the two great aspects of autumn are the inevitable ebb of life and all the many arrangements which secure that this does not go too far. Even if the individual cannot be saved, the race is continued perennially.

THE CLEANSERS OF THE EARTH.—Especially at the fall of the year, which is a great time for dying, the question rises: How is the earth kept so clean? What an efficient 'Cleansing Department' there must be, for there are so few dead animals lying about! All through the year, no doubt, there is this process of tidying, cleaning, and burying, but its thoroughness is very marked in autumn when there is much bare ground, yet there is little tangible evidence of the terrible thinning of the ranks of animal life after the crowdedness of summer.

Long ago W. H. Hudson drew a fine picture of the dying huanaco, that is to say, the wild form of the llama and alpaca—the small camel of South America. It seems that at the southern extremity of Patagonia the huanacos have a 'dying-place' to which they repair at the approach of death. Darwin noticed this on his *Beagle* voyage and pointed out that the exhausted animals must in most cases have had strength enough left to crawl among and beneath the thick bushes. This strange habit may in part express the natural desire of the aged or infirm to get away from the fatiguing bustle of the herd, and possibly to escape from the tendency some gregarious mammals have of getting rid of sickly or wounded relatives whose persistent presence is apt to be a source of danger. But both these suggestions sound very anthropomorphic, and we may safely conclude that the dying

huanacos do *not* set off on their final pilgrimage with the purpose of finding a quiet place to die in. Moreover, it is only in southern Patagonia that the huanacos have dying-places.

Much more credible, we think, is Hudson's theory that the dying-places were ancient shelters from the deep snow and deadly cold, and that the exhausted huanacos are still obeying an old instinct which climatic changes have robbed of its original significance. It is known that certain animals that become comatose in winter, such as some of the rattlesnakes, go back year after year to the old winter den; and it is also true of some of the true hibernating mammals that they go back to the same winter quarters over and over again. If this happened on a large scale, and if the lethargy and the winter sleep ended fatally, as they sometimes do, the result would be a cemetery distantly comparable to that of the huanacos of southern Patagonia.

But the point we wish to make is simply that many animals retreat to shelters beneath the ground, or in crannies among the rocks, or in crevices inside plants, where many of them die and are buried. The young queen-wasps of autumn, sole survivors of the large summer community, are hidden, each in her own place, under the thatch of a cottage or the loosened bark of a tree; and while some will 'sleep' the winter away, there are others that never reawaken.

Then again, no small amount of cleaning-up is due to the ceaseless conjugation of the verb 'to eat' that goes on in Wild Nature. So many animals depend upon 'crumbs' in the wide sense—minute fragments of plants such as fallen bud-scales, unconsidered trifles of insects, such as the dead bodies of midges killed by the evening frost. We have no great love for starlings when they become numerous, but it is interesting to watch the thorough way in which they advance in a long row over a lawn, pecking almost without stopping, and evidently making a good meal of minutiae, the nature of which in some cases we utterly fail to detect without a post-mortem. Thus one of the reasons for the cleanness of the earth is the circulation of matter which animal appetite secures. The dead creature is often devoured by another before it has had time to decay; its material substance finds a new embodiment, its protoplasm a fresh avatar. The flux of Animate Nature is a ceaseless cycle of reincarnations.

Those who live in the vicinity of deer forests have sometimes remarked on the relative rarity of the cast antlers—big, substantial organic structures which cannot very quickly disappear. Part of the explanation is that the stags eat their lost decorations, the erosions made by the lower incisors being sometimes clearly visible when the strange meal has been interrupted.

Especially in the autumn we cannot overlook the cleansing and tidying that is due to the burying activity of the multitudinous

earthworms. No doubt they are chiefly concerned with taking leaves and other parts of plants into their burrows, partly for food when they decay, partly to make the underground retreats more comfortable, but it is of interest to notice that their somewhat blunt instinct extends to things like feathers, as we have often demonstrated. We suppose that their instinct is to grip anything that is at all leaf-like or leaf-stalk-like, for we have also seen them burying little pieces of string and tangles of thread.

Ultimately, of course, the decay of a dead animal is due to the action of bacteria, which also bring about the rotting of withered leaves and herbage, but our question is why we see comparatively little of the dead bodies of animals. Many animals go into shelters, often underground; others are devoured, living or dead, by other animals; but there is another answer—to be found in the industry of numerous creatures that are professionally, so to speak, the sextons of the earth. Very typical are the species of *Necrophorus*, beetles that collect underneath a dead bird or the like and energetically dig a grave. Their instinct is to excavate the earth below the dead body so that there is a rapid sinking downwards. Fifty of these sexton-beetles, some in funereal black and other species more cheerfully attired, have been found working underneath a dead crow; and unless they are numerous they do not succeed with a largish animal. For they have to work against time, the ‘ object ’ being to secure a suitable cradle for the young. If the burial takes too long the tissues are apt to dry up, and flies are also likely to forestall the beetles. Either of these contingencies would be prejudicial to the beetles’ interests—it is very difficult to speak of ‘ purpose ’ or ‘ end ’—for the grubs must have a moist environment and soft food, and the fewer competitors they have the better. After the larvae reach their full size they leave their cadaverous cradle and pupate in the adjacent earth, eventually coming to the surface as sexton-beetles. The nearly related carrion-beetles (*Silpha*) often eat the dead bodies of small mammals and also use them as cradles, but in this group there is no burial. Thus the behaviour of Silpha may be regarded as a stage in the evolution of the carrion-using instinct, which has its fuller expression in Necrophorus.

If the dead body of a little mammal, such as a shrew, is left undevoured on the surface of the ground, and unburied by the sexton-beetles, it may pass through two stages. In the first place, it is almost sure to be utilized by flesh-flies of some sort as a receptacle for the eggs and a feeding-ground for the larvae. But after the larvae have become flies and flown away, what remains of the shrew’s body is exploited by animals which Verhoeff has called the ‘ secondary carrion fauna,’ such as several kinds of centipedes, various species of mites, some of the energetic ants, and not a few smaller beetles, such as a remarkable one

with the startling name *Thanatophilus* (the death-lover). Eventually there is nothing left but a little débris, which bacteria reduce to the lowest common denominator of the inorganic. This then becomes the food of plants and so enters on another incarnation. And so the world goes round!

Winter

WINTERING.—It is interesting to think of the variety of states in which common animals are spending the winter. The hedgehog is hibernating, but the mole is busy underground and the stoat is hunting over the snow. Most of the birds have migrated southwards, but the snow-bunting from the north finds our climate quite endurable for winter. Reptiles like adders and slow-worms have sought shelter in the secluded corners, shut off from wind and rain, and they lie in a lethargic state which is akin to the hibernation of the winter-sleepers among mammals and yet different. Frogs and toads are in holes in soft banks, or perhaps in a dry drain—mouth shut, nostrils shut, eyes shut, with the heart beating feebly and respiration going on through the skin. Some fishes swim about slowly below the ice, nosing hungrily here and there, saved by that property of water which secures a higher temperature below than above in the winter season. Most fishes seem very indifferent to cold, and the salmon may spawn in midwinter, which means, however, a slow development of the eggs.

Turning to backboneless animals, we find slugs deep in holes in the ground, and the snails buried in the recesses of an old wall. The snails have sealed up the mouth of the shell with a temporary lid of hardened slime and limestone, but their body shows some winter degeneration, and the heart beats very slowly and feebly. Earthworms burrow to a greater depth when the weather is very severe, and thus they get below the grip of the frost's fingers. The young queen humble-bees —the only survivors of the large summer household—are lying quaintly hunched up and deeply hidden in a mossy bank. The queen-wasp lies in the thatch or under bark or in some similar shelter. There are winter moths and winter midges flying about actively, but most insects are in a state of collapse. Not a few survive as adults, but the majority are lying low as **pupae** (e.g. the diamond-back moth), or as **larvae** (e.g. the so-called ' grubs ' of daddy-long-legs), or as **eggs** (as in the case of the hop-aphis). It is perhaps absurd to give a single example of each mode of wintering among insects, when there are so many of each; but it is a useful exercise to ask about each of the common animals: How is it wintering?

Every one knows that a squirrel stores nuts and that a brown stoat turns into a white ermine, but it is not always recognized that the

squirrel's store and the stoat's blanching go together, along with half a dozen other phenomena, as solutions of the problem of winter.

In northern countries winter means cold and scarcity, stormy weather and frozen ground; and animals have to meet these limitations and difficulties. This is part of their struggle for existence. So we see the Shetland pony with a shaggier coat and the badger with a store of fat below his skin. In both cases there is a conservation of the precious animal heat, which makes it possible for the chemical processes of the body to go on more quickly and smoothly. Moreover, the fat can be slowly burned away during the hard winter months.

Hamsters store hay, and we read that the Mongolian herdsman brings his cow in autumn to eat the haystacks which are so diligently built in the summer months by the quaint tailless hares. Some voles store vegetable supplies, and the mole has a larder of decapitated earthworms—a last resource when the frost grips deeply. It is the storing habit that has made it possible for the ants to continue as communities from year to year, and the same is evident in bees. Of the humble-bees that do not store, only the young queens survive through the winter; of the hive-bees, a large fraction of the population lives on into the next year.

The mountain hare or variable hare turns white, save the black tips of its ears, and the same kind of change is seen in other familiar cases, such as stoat and ptarmigan. It is often exhibited by the Arctic fox of Scandinavia, which, by the way, is also in the habit of making stores of food in caches beneath the snow. For the most part the blanching is due to a new growth of hair or feathers, in which the place of pigment is taken by a multitude of gas-vacuoles. The whiteness of a mountain hare is like that of foam; that is to say, the light is almost perfectly reflected from a multitude of mirror-like surfaces (cf. p. 830). There can be little doubt that the whiteness is to some extent a useful concealment—a garment of invisibility—against a background of snow; but its deeper significance is almost certainly that for a warm-blooded animal in cold surroundings a white dress is the most economical dress. It conserves the animal heat more effectively than a similar dress of any other colour (cf. p. 831).

Some animals meet the winter by tightening their belt and living more 'dangerously.' Thus the packs of wolves intensify the keenness of their hunting, and we read in a recent winter of the appearance of hungry wolves in parts of Europe where they have been complete strangers for many a year. The otter will swim underneath the ice—a dreadfully dangerous experiment—and we have heard of starving deer swallowing young rabbits, which is against all textbook zoology. What a contrast between quickening the pace and sinking into lethargy! The frog lies in a dried-up drain-pipe; the slow-worms

snuggle many-a-bed in the recess of a dry, mossy bank; the snail has sealed up its shell in a cranny of the old wall; and how many insects are lying low inside pupa-cases or cocoons! This points the way to the true hibernation of certain mammals like hedgehog and bat, which, being imperfectly warm-blooded, make a strength out of a weakness and survive the winter in confined spaces and sheltered corners. They relapse into a sort of reptilian cold-bloodedness, but it pays; and they emerge in spring none the worse for their long fast, all the better for their long rest. The neatest solution of all is that of the migratory birds, for they conquer the winter by circumventing it, 'changing their seasons in a night,' and having two summers in their year. There are other solutions besides those that we have mentioned, but our point here is simply this, that what the biologist does is to unify all these—as different solutions of the same problem, the problem of meeting the winter. They are different tactics employed against a common enemy. Their parallels with man's methods are interesting.

BUTTERFLIES IN WINTER.—In north temperate countries butterflies are naturally associated with summer and its flowers, but in warm countries, where the seasons are but vaguely punctuated, they are to be seen flying about all the year round, unless the summer is too scorching. Even in Europe, when we include the Mediterranean coasts with their generous winter sunshine, there is not a month of the year when we cannot see an active butterfly. Indeed, there are a few European butterflies, like *Hibernia*, that habitually fly about in winter, even in frosty weather. But our question is: What do ordinary butterflies do in winter?

The first part of the answer is that some of them normally spend the winter in the adult winged state. When the cold weather sets in, towards the end of September, they seek out sheltered places, often in woods and copses, and sink into a lethargic state. Not much is known in regard to this state of suspended animation, when income is nil and expenditure not much more; but it should not be called winter sleep or hibernation (p. 875)—a term best restricted to the remarkable physiological state into which some mammals—hedgehogs, marmots, dormice, and the like—sink at the fall of the year. Among the butterflies that are able to pass the winter as resting adults we may mention tortoiseshells, red admirals, painted ladies, and some hawk-moths. There is a long list of species that normally lie quiet as butterflies throughout the cold months.

Three points of interest may be noticed. If there is a spell of sunny weather, tortoiseshells or the like may waken up and fly about a little. They are sometimes called 'editorial butterflies,' because people send letters to the newspapers about them, calling them 'surprisingly early harbingers of spring,' which is hardly what they

are. In the second place, it is not surprising that red admirals and the like, which are normally quiescent in winter in North Europe, should be flying at that season in southern countries, such as Sicily. Thirdly, the butterflies that we have mentioned and others like them become quiescent as butterflies, whereas a thoroughgoing winter-flying butterfly, like *Hibernia*, begins the winter in the cocoon or chrysalid stage, and does not emerge until after there has been a sharp frost. This points to some deep constitutional difference, for frost is not usually an awakening stimulus.

Among the true winter-fliers the females have usually reduced wings, as in *Hibernia* and *Biston*. As the wings of the males are not reduced, the arrest of the females can hardly be referred to the frost. As Dr. Hering points out in his fine *Biologie der Schmetterlinge*, the reduction of wings in the females is probably an adaptation which counteracts the risk of being blown away by winter storms. The females, being laden with eggs, are heavier on the wing than the males, and cannot so readily make their way back again into the shelter of the trees under which they find suitable food-plants for their offspring. Moreover, it is profitable that some males should be blown away to other haunts, for this promotes cross-fertilization. It is often possible to discover the good that an ill wind blows!

The second part of the answer to our question is that the majority of butterflies survive the winter in the caterpillar stage. Perhaps the caterpillar is more resistant than the delicately built butterfly; perhaps it is easier for the caterpillar to snuggle into a retreat and also to shift its quarters if they become uncomfortable; most important, perhaps, is the fact that the caterpillar's body is rich in nutritive reserves. But there is another way of looking at the facts; the lengthening out of the caterpillar stage when conditions are unpropitious, is a mark of the more old-fashioned or primitive butterflies. Careful study of structure has led to the conclusion that among butterflies living in similar climatic conditions the more primitive species or even genera have the caterpillar stage long drawn out in proportion to the chrysalid or pupa stage. The more modern types, usually smaller and more specialized, have a relatively longer chrysalid stage.

Here it must be recalled that the more primitive insects, like cockroaches, locusts, and earwigs, have no true larval stage. What comes out of the egg is a miniature of the adult, except that it may not have wings. In the course of evolution there came about an interpolation of larval stages, partly in reference to difficult conditions (sometimes due to a lengthening out of the individual life which prevented the cycle being completed within the period that was not too cold or too warm), and partly in reference to the advantage of marking off

a growing and accumulating sexless phase from a multiplying and spendthrift sexual phase, and partly in solution of the problem of getting rid of the irksome and dangerous process of moulting after the winged phase was reached.

May-flies are the only insects that moult after they get wings. For these and perhaps other reasons, an adaptive larval stage was interpolated. In short, caterpillars evolved in order that there might be bigger and lustier butterflies. Or, if that sounds too much as though caterpillars arose of set purpose, it may be safer to say that a common variation among animals is to lengthen out and emphasize, or, contrariwise, to telescope down and minimize an arc in the life-curve. The production of larvae means that an emphasis has been laid on the juvenile period of life—before growing up; and there is a great deal to be said for having a long youth.

But this brings us to the third answer to what seemed at first such an easy question: How do the butterflies winter? On the spur of the moment, we think, many people would have answered this question by saying: 'Why, they spend the winter as quiescent pupae or chrysalids, often inside effectively protective cocoons.' But, as a matter of fact, wintering in the pupal phase is not nearly so common as wintering in the caterpillar phase.

For this there are two reasons. First, there is strong evidence that the interpolation of a pupal period is much less ancient than the interpolation of a larval period. This is borne out by the life-history of numerous insects, such as may-flies and dragon-flies, that have larvae but no sharply defined pupae. The pupal period is a preface to the fully formed insect life, in most cases quiescent and well protected so that the critical ending of the great change or metamorphosis may be safely accomplished.

It must be noted that a caterpillar has from the very start the foundations of wings, though it is not till the pupation that these come to their own. The pupa or chrysalid phase corresponds to the first chapter of the fully formed winged phase in simpler insects. Therefore, since the caterpillar is much older historically than the pupa, more butterflies winter as caterpillars than as pupae.

But there is another reason why more butterflies winter as caterpillars than as pupae. Caterpillars have the great advantage that they can shift their winter quarters if the conditions become too uncomfortable or dangerous, whereas pupae are usually fixtures. If butterflies winter as pupae, these are in most cases very effectively protected against frost, dampness, and enemies.

The fourth part of the answer is that a few butterflies pass the winter in the form of eggs. These are, as one would expect, well protected within their chitinous shells; and their vitality, no more than incipient,

is less likely to be harmed by wintry influences than that of the highly differentiated caterpillars or winged butterflies. But it is only in propitious environments and with hardy constitutions that wintering as eggs is feasible; and it is open to the disadvantage that most of the delicate operations of development have to be undertaken during the capricious weather of spring. It is interesting, however, as an evidence of life's resourcefulness that butterflies may spend the winter as adults, as pupae, as caterpillars, and as eggs.

HOW FLIES PASS THE WINTER.—Blue-bottles have been seen flying about the mouths of rabbit burrows in the north of Scotland (Aberdeenshire) on a frosty day at the end of November. It is probable that they find shelter in the recesses of the burrows, where the temperature would be higher than in the open. But one would like to know precisely in what state or states they pass the winter. There are often dead rabbits about the warren; does the life-cycle of the fly sometimes continue? The question has been studied a good deal in Britain in regard to house-flies, but it would be interesting to collect more information from different parts of the country and in regard to various kinds of flies. A recent inquiry in Korea shows that individuals of the house-fly (*Musca domestica*) may spend the winter as adults, and feeding experiments prove that the adult house-fly may live for more than 120 days in winter. The adult house-flies referred to were not torpid, but continued to move actively and to breed. Inquiry into the ways of blow-flies and stable-flies go to show that different species pass the winter in different states—some as adults, some as pupae or larvae.

A POND IN WINTER.—When we look into a clean and natural pond in the height of summer we see a great bustle of life; in winter the water seems empty and barren. But we have recently got an interesting glimpse which goes beyond the obvious and superficial. The researches of A. H. Drew and others go to show that the dying away of living things, which takes place in the pond in autumn and winter, results in the production of peculiar chemical substances conducive to growth (**auxetics**, they are called), which later on promote the multiplication of single-celled organisms in the water. Later on, towards the spring, there is a production of other chemical substances (**augmentors**) which give more power to the elbow of the first. And so out of death come the stimulants to the wonderful awakening of pond-life in spring, from which many consequences flow. It seems to us that we have here an illustration of one of the biggest ideas in regard to the biology of winter, that it is a season of *preparation*. Hence science and common sense are agreed.

A BIOLOGICAL WALK IN WINTER.—In northern or southern countries winter means, for familiar astronomical reasons, a great reduction in

the supply of light and heat that the earth receives from the sun. This primary difference between winter and summer has associated secondary differences, such as the shorter day (in which plants and animals can do their work); various conditions, such as lessened evaporation and the binding of the earth with frost, which greatly hinder the circulation of water (the meteorological cycle, as it is called); the fall of snow with its many benefits and many risks; also severe storms, and so forth. We all know, more or less, what is meant by winter—the annual recall of the Ice Ages of the past, oftenest ages of severe sifting, but occasionally of progressive effort.

If we take a biological walk in summer, when life has its high tide, our difficulty often is that there is too much to see. The stage is crowded; there is a bustle of life in hedgerow and meadow, in pond and on shore. In winter, however, there is often relatively little to see, unless we have plenty of time and more than the average man's knowledge of where to look for the creatures that are in hiding. Often, especially in the north, we must be content to see two or three things each day, which gradually combine into our winter picture. We envy those who are able, through long patience and practice, to identify all the footprints on the snow; to tell us where the hedgehog is lying in his winter sleep; what 'winter-visitor' birds have come to the estuary; where the frogs are ensconced stiff and stark, mouth shut, nose shut, eyes shut, hardly breathing at all; where the bats are hibernating, hanging head downwards by their toes, and wrapped up in their leathery arms; and so on.

When in America, we went one day into the Californian desert with a naturalist who knew it well, and we had not been there five minutes before he said: 'Do you know the lizard called *Xantusia*? There's a species here that lives under the loose bark of the Joshua tree, hunting for spiders and other small fry. There's just the sort of place where it lives.' Whereupon he laid his hand on the loose bark of the tree in question (one of the yuccas, a sort of tree-lily), and produced a much-startled Xantusia! It looked like magic, but it was only a vivid instance of that observational skill which all of us can in some measure attain along some line or other. It certainly adds to the joy of life.

Winter, as we have said, is *a time of lying low*, as in the snails shut up in their shells far in the recesses of that old wall. Below the level of the shell-opening there is a lid of hardened limestone and slime, with a small aperture through which an interchange of gases takes place. The snail itself is in a somewhat collapsed state, for its heart is beating very, very feebly, and the tissues of one that we dissected were distinctly under par, worse than flabby.

Before we pass the old wall we must pay tribute of admiration to the lichens which are spreading in strange orange-coloured patterns over

the stones. Does life ever endure under greater difficulties—exposed on the surface of a wall? Fine threads insinuate themselves into microscopic crevices and absorb dissolved salts; the coloured part of the lichen absorbs air and the green cells build up carbon-compounds, just as in any ordinary green leaf. The secret of success is partly this, that every lichen is a combination of two quite different plants—a green alga and a colourless fungus, which work into one another's hands (symbiosis) and prosper. In the circulation of matter that is always going on in the world these lowly lichens play their part, for they begin the weathering of the rocks, and we find them at work on the tops of the hills, making a primitive kind of soil which is eventually carried by runlets and streamlets to the distant valley and the farmer's fields.

If you have time to rest on the wall it is interesting to pull off some of the low-growing moss, which flourishes in the soil that the lichens have made, added to, no doubt, by dust-particles blown upwards from the road and carried down by the rain, helped also, of course, by the dead bodies of small creatures, both animals and plants, which bacteria have decomposed. When we uproot some of the mosses (to be packed into a hole when we pass on) we disclose a Lilliputian world, which a lens helps us to scrutinize. There are the tiniest snails and just visible worms, there are miniature insects and their larvae, also some very interesting primitive wingless insects and some old-fashioned millepedes. We were pleased to find an old friend called *Orthesia*, a squat ca' canny insect, with a wax-white trailer behind its body, and this was full of developing eggs. Ever so much smaller, of course, are the microscopic animals of the primitive soil of the wall crevices. With these there are few of us who can do much, but it is worth while to select a hundred yards of old wall and chronicle, week after week, the plants and animals that we can find on it, without including those that we cannot see with the naked eye. We soon discover that life is much more abundant—even in winter—than we at first suspected.

Among the many different forms of 'lying low' in winter we must include:

(*a*) The relapsed life of some insect pupae, where the body of the larva (e.g. maggot) has become greatly simplified in structure, in fact almost embryonic again.

(*b*) The arrested development of other insect larvae, such as caterpillars and pupae, where the metamorphosis into the winged form has ceased for the time being, like a stopped watch.

(*c*) The suspended animation of many small creatures, like bear animalcules (some of them quaintly like microscopic hippopotamuses) and wheel animalcules and small threadworms, in which we can detect no vitality for the time being.

(*d*) The comatose state of snails and frogs, where we can see the beating heart, though the life of the body as a whole is at a very low ebb.

(*e*) The state of true **hibernation,** restricted to a few mammals, such as hedgehog and dormouse, marmot and bat. Unlike ordinary warm-blooded mammals, and birds too, which are able to keep up the same body-temperature year in and year out (which is what 'warm-bloodedness' means), the imperfectly warm-blooded types, such as the four mentioned, are unable to produce enough of animal heat to make good what they are losing in the cold weather. So they sink back into a peculiar state, very unlike normal sleep, with most of the vital functions (even excretion) in abeyance, with the heart beating very feebly, and the breathing movements scarcely perceptible. This *relapse* into reptilian cold-bloodedness (for mammals evolved from an extinct reptile stock) would soon be fatal in the open; but it is linked to the instinct to seek out a sheltered nook, where the temperature soon rises a little above that outside, and the retreat is warmed enough to keep the blood of the winter-sleeper from freezing.

Along with the lying-low solution we must include the discovery of shelter, and this habit accounts in no small part for the bareness that marks our country walk along the path, through the copse, across the stretch of moor, and along the river-side. There are many more animals than we see; they are hiding in shelters difficult to find. We split up twelve hemlock stems with a knife, and found twelve animals right away. In some cases, to be sure, the shelter is not here, but far away; and this brings us to the migration solution—conquering the winter by evading it. As we skirt the low moor we see some white hares scampering; they have put on a white dress which economizes the loss of heat, and may also provide a cloak of invisibility against a background of snow; but the point just now is that these variable hares have migrated from the high hills, where the food is too deeply covered by snow, to the low grounds where they run an obvious risk from conspicuousness, but none of starvation. So the reindeer migrate in Newfoundland, and the majority of our British birds seek the south.

Where the river joins the sea we may be lucky enough on our walk to discover a little auk, a great snipe, a northern diver, or some other 'winter-visitor' bird, which finds our shores quite genial compared with the severities of the Arctic breeding-places frequented in summer. On the links we met a flock of snow-buntings, singing in their flight, just arrived from across the North Sea, and making for the fields where they may refresh themselves with seeds after their long journey. Those of us who live in the north of Scotland sometimes find it a little difficult to believe in creatures that choose our country for winter quarters.

As we stroll along the river, which has ice at its edges in many places,

we notice the scarcity of life; and this strikes us most in regard to certain flood pools or miniature ponds which we know to be teeming with animals in the summer. Most of their tenants are in hiding, and we feel a deep-down gratitude that water has the almost unique property of expanding as it freezes. As we have already mentioned, its maximum density, when the molecules are most closely packed, is at 4° C., and if the temperature falls further, towards the freezing-point or zero, the volume increases and the freezing-water rises to the surface of the pool, where it forms a blanket of ice. Thus in winter the temperature at the floor of the pool is higher than at the surface; it is, therefore, difficult for the pool to freeze solid; and this means a very important conservation of aquatic life during the cold months in northern and southern latitudes. No wonder that people have written panegyrics of water!

From Water was everything first created!
Water doth everything still sustain!
Ocean, grant us thine endless reign!
If the clouds thou wert sending not,
The swelling streams wert spending not,
The winding rivers bending not,
And all in thee wert ending not,
Could mountains, and plains, and the world itself be?
The freshest existence flows ever from thee! [1]

Our walk takes us through a little wood, including some fine beech trees, and the crickle-crackle of the leaves beneath our feet reminds us of another way in which living creatures meet the winter—by retrenchment and by reduction of vulnerable surface. The leaves have worked hard all the summer, making carbon-compounds, and they must be in some measure worn out. After they have surrendered to the branches almost all that they have that is worth having, they are separated off and fall to the ground, where the earthworms bury some of them, thus adding to the invaluable vegetable mould, soon to be reincarnated in the trees. So the world goes round; but our present point is simply that it pays most trees to shed their leaves in the fall. It is a useful reduction of vulnerable surface, for ordinary leaves that managed to continue with abundant water in their cells and vessels would run the obvious risk of having these ruptured by freezing.

The same retrenchment or reduction of vulnerable surface is observed in some zoöphytes and even more complicated animals, but the adaptation is especially characteristic of plants. Yet we see it on a higher turn of the spiral when all the humble-bees of the summer community and all the wasps of the nest die off in early autumn, except the young queens, which alone survive the winter.

[1] Goethe; Bayard Taylor's translation.

It is interesting to go back to one of the river pools where the washed roots of the alder trees and the bases of the bulrush stems are encrusted with the freshwater sponge. This was vigorous and distinctly green in summer, the green colour being due to countless numbers of microscopic partner-algae, whose manufactured carbon-compounds help to feed the sponge; but now it looks rather the worse for wear. It is moribund, but all through its body there are clusters of cells forming microscopically beautiful gemmules, which live on and start new sponges in spring.

The corner of the moor looks rather fine in the winter sunshine which lights up the withered bracken. But, except aesthetically, we cannot approve of it, for the bracken is a disastrous weed, spoiling fine pasture-slopes and conquering even the heather. As we look at it we know, of course, that all we see is dead; yet next year it will be more luxuriant and rampageous than ever. The secret is all too familiar, that the strong underground stem or rhizome is well protected beneath the ground, and richly stored with nutritive reserves which will be mobilized in spring. So storing is another way of meeting the winter; and we can link the bracken to the squirrel with its stores of beech nuts in the wood—so different and yet the same in idea.

As we came back again towards the farm, an interesting thought arose in our mind, that man often follows Nature more than he knows. Thus in regard to this problem of meeting the winter, many of the human solutions are closely parallel to Nature's. More or less unconsciously, similar problems find similar solutions. Many animals go into hiding or shelter; so man brings his cattle in some measure indoors. In the 'black houses' of the Hebrides, the cow is brought, on the approach of winter, into one end of the crowded dwelling, for it requires less food indoors and is safe from storms. When spring comes, it has to be lifted out, so great is its weakness. So some species of ants take *their* cows—the green-flies or aphids—into an underground stable for the winter, and look after them too, till they can be carried out again in spring, for the day at least. In some cases the *vaccae formicarum*, as Linnaeus called them, are taken into shelter every summer evening; and again we think of man calling the cattle home.

The farmer provides for the winter by storing food, such as hay and turnips, for his stock, following the lead of the hamster with its chopped grass, the beaver with its cut branches, the squirrel with its beech mast, the hive-bees with their honey, the Californian woodpeckers with their thousands of acorns firmly fixed in holes in the bark of oak trees. Our fathers knew the change involved when the extended cultivation of turnips made it possible to feed cattle and sheep in a satisfactory way throughout the winter, the farmer thus utilizing the plant's nutritive reserves for a secondary purpose of his

own. In a way this is very elementary, though it is a thought worth pursuing, that man, consciously or unconsciously, has followed Nature in various solutions of the problem of winter. But after all, man is a child of Nature.

We look into the stable and we see some of the more delicate horses well wrapped up in horse-blankets, thus afforded the advantage which many wild creatures attain by thickening their coat of hair. How shaggy the domesticated Shetland pony becomes in winter, just like the yak amongst the snow on the Tibetan uplands! At the end of summer the Swiss crofter brings his cattle and goats down from the 'alp' (as his high-level pasturage is called) and keeps them in shelter till the snows have gone—a device evidently paralleled by the migration of many birds and mammals.

We have spoken of the drastic elimination that is often characteristic of winter, and we can never forget one deadly night of frost after which were gathered about two hundred dead birds (a big barrowful) from one farm-steading. So man reduces his stock, sometimes beginning with those that are least promising of survival, but sometimes beginning with the best, in the hope of fattening up the others.

We need not pursue the Farmer-Nature analogy further, and we have too much respect for him and for ourselves to speak of the farmer as hibernating, though there is an approach to this in some remote parts of the U.S.S.R. when the inmates of the farmhouse huddle together round the stove and do not really waken except at long intervals. Better than that would be another biological walk!

WINTER VISITORS.—The birds of a country may be grouped, in reference to migration, as residents, partial migrants, summer visitors, winter visitors, and birds of passage. In Britain the residents, which do not migrate at all, may be illustrated by red grouse and house-sparrow. The partial migrants, which are never unrepresented in the country, though some of them migrate, may be illustrated by lapwing and goldfinch. Of the summer visitors, nesting here and wintering in more genial countries, every one will admit that swallow and swift, cuckoo and nightingale are good types. The birds of passage in the true sense, that spend a short time with us on their way between their summer and winter haunts, may be illustrated by blue-throat, Lapland bunting, great snipe, little stint, spotted redshank, and grey phalarope. Of the winter visitors, like redwing, fieldfare, great northern diver, little auk, and golden-eye, we wish to speak in more detail, for they are a great delight in the cold months when so many old friends have gone. They are normally absent in summer and they do not nest in this country, though there are occasional exceptions to both these statements.

Redwings and fieldfares often congregate in the bare fields, a merry

throng searching for small fry. They are very like their first cousin the song-thrush, but the redwing may be distinguished by the chestnut colour under the wing, visible when it takes to flight, and the fieldfare by its slate-grey rump and its harsh call. When these birds can find no insects, slugs, or worms in the fields, they search for haws, holly berries, and the like on the trees, but many of them have a very hard time. They nest in the north of Europe and Asia, especially in regions where there is great abundance of insects during the summer months.

One of the most beautiful of our winter visitors is the brambling, not greatly excelled by its first cousin the chaffinch, with which it often consorts under the beech trees or in the open fields. When the two species rise together the bramblings may be distinguished by their white rump, and the bright chestnut of the shoulders is also noteworthy. They feed largely on the beech mast and on the seeds of weeds in the fields, but they are also fond of small insects and their larvae. Another beautiful bird is the snow-bunting or snowflake, which may be justly associated with snow and winter, and often arrives in little flocks on the north-east coast of Britain in wintry weather. It seems hardly justifiable to exclude it from the list of winter visitors, on the ground that a few are known to nest every year on the mountains of the Scottish Highlands, such as Ben Wyvis.

A good type, though relatively a rarity, is the waxwing, whose visits never fail to attract attention. At the tips of several of the second-longest wing-feathers, and sometimes on the tail as well, there are peculiar little knobs like droplets of red sealing-wax. They occur in both sexes and their significance is unknown. Perhaps they have none, but they might repay chemical analysis. Another striking feature is the erectile crest. These 'Bohemian waxwings,' or, worse still, 'Bohemian chatterers,' have nothing to do with Bohemia, and they are very quiet birds. They nest in the coniferous forests of the far north, and it is only at intervals that they appear in large numbers in Britain. They seem to enjoy the hips and haws, and it is matter for regret that they should be so often greeted with a shot. It is ridiculously characteristic of man's inhospitable outlook that the visits of these attractive birds should be called 'invasions.'

To the Orkneys and Shetlands and Outer Hebrides the impressive glaucous gull is a frequent winter visitor; and it comes further south in hard weather. We say 'impressive' because the 'burgomaster,' as it is often called, is as big as the great black-back, and because its predominantly white colour is congruent with the snow, and because it is such a bullying, predatory bird. It has a hefty appetite for dead whale and seal, but it is fonder still of birds smaller than itself. It is a typical 'each-for-himself' creature, but a good parent none the

less. The Iceland gull, likewise whitish, yet less white, might be also ranked as a winter visitor.

Now we come to the practical difficulty of our survey, that whereas the list of our winter visitors includes two thrushes, two finches, two gulls, and so on, to which we can refer individually, there are numerous ducks and geese, and numerous plover-like birds. Thus, to be more precise, the white-fronted goose, the bean-goose, the pink-footed goose, the barnacle-goose, and the brent-goose are all winter visitors. So is the whooper-swan and Bewick's swan. And similarly for various wild ducks, like the charming golden-eye, the velvet scoter, the long-tailed duck, and the smew. The same may be said of the plover-like birds; there are more of them than we can refer to individually. We think of the grey plover, the interesting turnstone, the jack-snipe, the knot from the far north, the sanderling, and the bar-tailed godwit. All these are winter visitors, never nesting within British bounds, always breeding further north, yet more or less familiar in cold weather on the shores of estuaries and sheltered bays along our coasts. The fact is that the majority of our winter visitors are duck-like or plover-like; and we suppose that this means that northern waters and marshy grounds are swarming in summer with nutritive small fry.

When we were sitting by the shore one winter day in the shelter of a pulpit-like rock there came to our feet a little auk. It looks almost ridiculously small—only about six inches long—one could hardly think of it weathering the open sea and nesting on the Arctic islands. Its black and white dress, its short, conical beak, its quick, quiet movements, gave one the impression of extraordinary neatness. It did not see us for a while, but when we moved our head it dived, using its wings under water. This is its habit when feeding on the small shrimp-like crustaceans which form its staple food. It is an interesting winter visitor, this distant relative of the extinct great auk, but its coming is often fatal. A spell of stormy weather means scarcity of food, for the crustaceans descend out of reach; the birds become weak and flurried; some are wrecked on the cliffs, and others are borne far inland, where they hurl themselves against obstacles to which they are unaccustomed.

As a climax to our illustrations of winter visitors we may take the great northern diver, which does not breed nearer than Iceland, but is often seen on British seas in the cold months, and even on inland lakes. It is a truly magnificent bird, approaching a yard in total length, with very striking plumage, especially at the breeding time in spring. The powerful dagger-like bill is as effective in fish-catching as are the feet in swimming and the wings in flight. The 'loon,' as it is often called, is unsurpassed in diving, and it can remain two or three minutes under water. One busy bird, timed by Mr. Coward, spent fourteen and a half minutes out of a quarter of an hour below the surface, so its five or six

appearances above water must have been literally momentary. To be appreciated aright the great northern diver must be seen at work in the water, for it shuffles awkwardly on land, with the body held low. It cannot rise off the ground, and even among the waves it makes much splutter before it gets launched on its powerful flight. It is a bird of long pedigree, perhaps related to the extinct toothed *Hesperornis*. Altogether it is such a thrilling creature that it is worth having a winter to bring this visitor alone.

WINTER WAITING.—It may be interesting to pause for a little to look at spring in the light of winter. In the early weeks of spring we begin to see a stir among living creatures. In many places the rooks have built their nests; the wild geese have flown to their nesting-places in the far north, and we heard them 'honk-honking' as their great V-shaped phalanx passed quickly overhead; we have seen the small tortoiseshell butterfly sunning itself after its winter's rest; and there are many other evidences that spring is here. But to ordinary eyes it seems that there is not much doing, and as a general impression that is quite sound Natural History. For Life in its glory is waiting.

Under an old coat of arms, whose we know not, we read the words 'I bide my time,' and this quality of waiting with readiness or determination is very characteristic of many living creatures throughout the winter. Let us think of it, even if it means a little repetition.

Many winter-sleepers, like hedgehogs and dormice, have been waiting through the months of cold and scarcity, saving their lives by 'lying low and saying nuffin,' in Brer Rabbit's language. Some of them will be the better, not the worse, for biding their time; they may be more energetic when they awaken than they were when they fell asleep. Other creatures that do not hibernate in the strict sense, but simply fall into a lethargic state, like slow-worms and tortoises, frogs and toads, snails and various full-grown insects, have also been waiting. There are dangers, of course, in this, for the fire of life may burn so low that some winter storm blows it out altogether, but in many cases the long rest is for the creature's good. It is the crouch before the leap. It is often a chance for warding off old age, just as an overworked man may avoid a break-down by taking a week-end in bed.

In the case of a great many insects the waiting time is spent in the chrysalid, or cocoon, or pupa state; and the creature, well protected from cold and damp, may during part of the time be changing its bodily architecture, so that what went into winter quarters as a caterpillar or a grub comes out in spring—with its dreams come true, shall we dare to say?—as a butterfly or a beetle. It bides its time during a period when the outside world is apt to be too severe for delicate young lives, but it also utilizes the time by undergoing what is in some ways the most remarkable reconstruction in the world.

In a sheltered hole in a mossy bank has been lying a queen humble-bee, born last year. She, too, has been biding her time—when the catkins show on the willows. She and her sister queens are the sole survivors of the large family, we may almost say community, that crowded the nest last summer. With spring the whole bustle has begun again, for each surviving queen will, if she is lucky, start a new nest. In the same way the only survivors of the populous wasps' nest of last summer are the young queens which have slept all the winter hidden in the thatched roof of the cottage. Each by herself bides her time, holding firmly by her mouth, with her legs hunched up, presenting a remarkable resemblance of attitude to that of the pupa stage inside one of the cells of the wasps' nest.

What is true in the animal world is not less true among plants—there is safety for many in biding their time. The seeds, well protected by their dense coats, lie waiting in the ground—waiting for the increased warmth and the soft rains of spring. There is a deep saying of one of the old naturalists, that the grain of wheat in the earth is dimly aware of what is going to come of it, and dreams of it dully every day. It is possible, for all we know, that a certain degree of that awareness which man has so vividly may be shared by every living thing. Besides the seeds, there are the outwardly unpromising bulbs and tubers. What condensations they have been of magnificent possibilities! To circumvent the difficult season there has been a retreat into condensed, scarcely vulnerable form. When the time comes there is the reward of patience—to all of us one of the delights of spring. Travellers in the steppe-lands to the north of Asia have described the wonderful transformation scene of every springtime. Before the last snow-wreaths have vanished, the bulbous plants begin to put forth their leaves and raise their flower-stalks to the sun. 'Buds are unpacked, flowers unfold, and the steppe arrays itself in indescribable splendour. Boundless tracts are resplendent with tulips,' and after the tulips come the lilies.

Besides the seeds and the bulbs there are the buds, formed in the strength of last summer's sun. Well protected by their tightly fitting, often well-varnished scales, they have remained quiescent during the dangerous winter months, biding their time. In a few weeks the increased warmth and the associated uprush of sap has set growing going again—the scaly envelopes have burst, and the bud grown out into a shoot or unfolded into a flower. The blackthorn, or sloe, which a few weeks ago looked like a bare skeleton, is now covered with snow-white blossom. Out of the uninviting ditch the marsh marigolds have raised their golden cups—their 'king-cups'—to be filled with sunshine. They, too, have had the reward of biding their time.

At each well-marked time of year there is some general impression

that we should try to get. So when we think of the bat hanging from the rafters of the barn, the frog lurking in a comatose state in a hole under moss, the snail in the wall with the door of its shell closely shut, the hundreds of different kinds of chrysalids and pupae in secure hiding-places, the seeds lying in the earth, the shoot in miniature within the bud, the glory that is concealed in the bulbs, we feel that a very true impression of Nature is expressed in the words: 'Biding their time.'

CHAPTER IV

VARIOUS ASPECTS OF ANIMAL LIFE

Our legacies from the Dark Ages of science—Strange animals—Some Bible animals—Some odd American animals—Treasures of St. Kilda—The seven wonders of life—Animal sanctuaries: natural and artificial.

Our Legacies from the Dark Ages of Science

Many precocious children become very dull as they grow older, and then recover themselves at adolescence. The same has been true in the history of science. What geniuses there were in early days—Aristotle, Archimedes, Hippocrates, Eudoxus!—and ancient science can be traced as an activity long after these foundation-layers, indeed up to the end of the second century of the Christian era.

Ptolemy, who died about A.D. 160, is regarded by many as a cosmographer of the first rank; and Galen, who died in A.D. 200, was one of the few great biologists; but after these a thick darkness began to set in as far as Western science is concerned. The Dark Ages of Europe began, and apart from a few rare exceptions, like Roger Bacon, the darkness was not finally relieved till about the middle of the sixteenth century. There was, however, a partial scientific renaissance in the twelfth century.

In his learned, illuminating, and fascinating book, *From Magic to Science* (Benn, 1928), Professor Charles Singer, one of the best authorities on the subject, selects 1543 as the end-point of scientific medievalism. For in that year there appeared two fundamentally *modern* works, which marked the great scientific renaissance — the work of Vesalius on *The Structure of the Human Body*, and the work of Copernicus on *The Revolutions of the Heavenly Bodies*. By these and by the wider freedom of mind of which they were expressions, the fetters of authority were broken; independent observation (not as yet experiment) was recognized as the path of progress. Copernicus was, as it were, looking forward to Galileo, and Vesalius to Harvey. This was the beginning of scientific adolescence. It was probably associated with an amelioration of the social conditions which the development of science requires.

It is one of the overwhelming facts of history that science, which had begun so well among the Greeks, passed (as far as Europe is con-

cerned) into a state of dull collapse for many centuries, perhaps one may say twelve. The kindest thing that can be said is that men were preoccupied with the practical tasks of civilization alike in peace and war.

It cannot be said that science was favoured either by the self-preservative Church or by the widespread short-sighted utilitarianism. No doubt there was technical scholarship and much writing of commentaries, much theological disputation, and some philosophizing; but even the *desire* to make new knowledge seems to have become dormant.

Of course all these statements are too general; thus Professor Singer lays emphasis on *The Age of Arabian Infiltration* that divided the early *Dark Age* proper from the later *Scholastic Age* which brings us to Copernicus and Vesalius. Nor can one ignore some useful factors in the mathematical and cosmographical inheritance from the Greeks, made available by translation from Arabic into Latin, but these did not avail to keep Natural Science awake in Christendom.

Another saving clause must be allowed for the occasional emergence of anticipators, such as Roger Bacon in the thirteenth century; but the large and dismal fact is the slumber of the scientific spirit in Europe for many centuries, a slumber broken by evil dreams. For the punishment of irresoluteness in learning to know is not merely dullness, but degeneracy—something perverse and pathological; and this brings us to magic.

'Magic' is almost as difficult to define as 'religion,' but in a general way it implies a naïve and uncritical investing of natural objects and forces with spirits which can be forced to do what is willed by the magician or by the believer in magic. Magic is said by many authorities to be antecedent to religion; but into it a debased religion may relapse. Magic is antithetic to science, since it regards Nature as capricious and lawless; yet into it a degenerate science may relapse.

What we should try to realize is that a relapse into magic is the punishment of disloyalty to science and to the scientific mood. Thus in the Dark Ages, when people ceased to wish to see for themselves, there came into currency a counterfeit Natural History that projected instead of scrutinizing; credulous superstition and perverted fancy ran riot on paths which should have been sacred to the discovery of facts. Strange dogmas became tyrannous, such as that of the supposed close correspondence between man (the microcosm) and the outer world (the macrocosm); or the doctrine that plants and animals are enswathed in symbols that are meant to give man some hint of their uses.

In spite of Galen's dissecting, the most whimsical pictures were made of the anatomy of the human body. The question of correspondence

to facts was not raised. All sorts of fanciful animals were invented, believed in, discussed; and even drawn.

We should like to have a clearer understanding of man's scientific relapse and of his recovery. What exactly were the factors that brought on the darkness, and what were the emancipating factors that in the fullness of time made the works of Copernicus and Vesalius not only possible, but acceptable? What led men to see the folly of their ways, so that they returned, not through magic, but from magic, to the quiet tasks of observation, to be soon followed by experiment?

But it is important to understand that many of the superstitions and ugly stories about animals that still linger are part of our legacy from the Dark Ages.

In contrast to the state of affairs prevailing in Europe, we have the picture of earnest devotion to science presented by medieval Islam. The Moslem scientists of the ninth to thirteenth centuries kept the spirit of science alive, and made many notable discoveries, particularly in chemistry (a science which they may be said to have founded), optics, hydrostatics, mathematics ('algebra,' for instance, is as Arabic as its name), and medicine. It was, indeed, from Islam that science was reintroduced to Europe, mainly by way of Spain and Sicily.

The moral of the history of science is to cultivate the habit of seeing for ourselves; to lose that desire is always disastrous. And we need to be warned, for the medieval mind still lurks in our midst.

Strange Animals

There is an ancient legend, told by a Chaldean historian, of a strange being whose head and upper part of the body resembled a man, while the lower part showed the tail and scales of a fish. This was the fish-god Oannes; he came ashore every morning on the coasts of Babylonia, and spent his days teaching the uncivilized people of that region the elements of the arts of life. At dusk he withdrew to the sea, and his nights were spent beneath the waves.

Many of the older historians have repeated this tale, and representations of Oannes have been found on ancient seals and monuments. Other nations had similar legends with corresponding deities. Thus Dagon, the god of the Philistines, who fell down before the Ark of the Lord, and Atergatis, the sea-goddess of the Syrians, were supposed to have been other forms of the Oannes tradition. In classical mythology the sea-goddess became Aphrodite rising from the waves, her form now pure woman. But her attendant nymphs, tritons, and

the like had still the fish-tail, and these, with many other mingled forms of man and beast, or beast and bird, are frequently depicted on ancient sculptures and frescoes.

It is not easy to determine how far medieval ideas of animals were influenced by these myths, or by the tales of strange and terrible creatures, such as fire-breathing dragons and many-headed serpents that abound in the folk-lore and fairy-tales of all countries, but some of them are marvellous enough. Our knowledge of them is largely due to 'Sir John Mandeville,' about whom little, not even his real name, is known. He wrote or brought together, in the early part of the fourteenth century, a collection of tales professing to be the result either of his own observations, or of information gathered in the course of his travels. Later investigation has shown that his travels were by no means extensive, and that his book is almost wholly a compilation from older sources. The tales were probably first written in French, and afterwards translated into Latin and many other languages. After the introduction of printing, the book became very widely known, and, till it was discredited by genuine observation, equally widely accepted.

If we cannot now accept the tales we can still in some measure enjoy them! By the time the tales were written, the idea of wandering deities had disappeared, and most of the animals were to some extent founded on fact, but there was still the tendency to people the but rarely fathomed depths of the ocean with creatures that had their counterpart on land, but were supposed to have sea characters superadded. Until the sixteenth century or so, the magical element had by no means wholly died out. Some of the tales are so marvellous that we feel that the writer must have had an almost foolishly credulous mind, or that he must have believed in the almost unbounded credulity of his readers. He was not easily disconcerted either, for when travellers from the East told him that in their country there grew a plant bearing pods, inside which were little lambs good to eat, he replied that that was nothing to what grew in his own, for there one might behold seaside trees bearing fruits which turned into geese. If these 'barnacle-geese' fell into the sea they lived; but if they fell on land they unfortunately died.

Two forms of the **vegetable-lamb** are depicted and described. In one the 'lamb' is borne on the end of a long stalk. 'It was in form like a lamb, and from its navel grew a stem by which this zoöphyte or plant-animal was fixed, attached like a gourd to the soil below the surface of the ground, and according to the length of its stem or root it devoured all the herbage which it was able to reach within the circle of its tether. The hunters who went in search of this creature were unable to capture or remove it, until they had succeeded in cutting the

stem by means of well-aimed arrows, or darts, when the animal immediately fell prostrate to the ground and died.'

The other form was the one of which the travellers told Mandeville —and apparently showed him, for he says: 'Of that fruyt I have eaten.' The tree 'groweth a manner of fruyt as though it weren gowrdes,' and within each of these fruits was a little lamb with flesh, bone, and blood, but without wool. Apparently the whole fruit with its contents could be eaten.

The story of the **barnacle-geese** which develop from the fruit of a tree is found in the works of very many writers from the eleventh century till the seventeenth, though in the later works it is put forward with less assurance than at first. A botanist, Gerard, writing before the end of the sixteenth century, figures and describes 'this wonder of England, for the which God's name be ever honored and praised.' 'There are to be found in the north parts of Scotland, and in the islands adjacent, called Orchades, certaine trees whereon do grow certain shells of a white colour tending to russett, wherein are contained little liuing things, which shells in time of maturitie do open and out of them do grow those little liuing creatures, which falling in the water do become fowles, which we call Barnakles, and in Lancashire tree-geese, but the other that do fall upon the land perish and come to nothing.' The author is evidently a little doubtful about this, for he says that he has only read or heard about it, though it may very well be true. But he goes on to tell what he really has seen on an island in Lancashire—pieces of old ships and rotting trunks of trees covered with shells like those of mussels but more sharply pointed, and containing something like a finely woven piece of silk or lace. 'When it is perfectly formed the shel gapeth open and the first thing that appeareth is the foresaid lace or string; next come the legs of the bird hanging out, and as it groweth greater it openeth the shel by degrees, til at length it is all come forth and hangeth onely by the bil; in short space afterward it cometh to full maturitie and falleth into the sea, when it gathereth feathers and groweth into a fowle bigger than a mallard and lesser than a goose.' There is no doubt that Gerard saw and examined living barnacles, but he took the rest of the story on trust, and we need not follow his description of the bird.

There were other birds hardly less wonderful than the barnacle-goose—which indeed is a familiar bird enough, the marvel being in its vegetable origin. The **phoenix,** of which there was only one in the world, was from very early times firmly believed in, and it has been immortalized in imagery because of its accredited habit of destroying itself on a fire of sweet herbs, when its powers began to fail, and arising again from the ashes, first a worm, then an egg, then the great bird itself renewed in youth and splendour:

Two sparkling eyes; upon her crown, a crest
Of starry sprigs (more splendent than the rest),
A golden doun about her daintie neck,
Her breast deep purple, and a scarlet back,
Her wings and train of feathers (mixed fine)
Of orient azure and incarnadine.

. . . . . .

While by a prosperous death she doth becom
(Among the cinders of her sacred fire)
Her owne self's heir, nurse, nurseling, dam, and sire.

The griffin, gryphon or gryffon was a great flying creature of whom 'Sir John Mandeville' has much to tell us: 'Some say they have the body before as an Egle, and behind as a Lyon, and it is trouth, for they be made so, but the Griffen has a body greater than VIII Lyons, and stalworthier than a hundred egles. For certainly he will bear to his nest flying a horse and a man upon his back, or two oxen yoked together as they go at plowgh, for he hath long nayles upon his feet, as great as it were horns of oxen, and of those they make Cups there to drink of, and of his ribs they make bows to shoote with.' Ser Marco Polo, a traveller of later date, identifies the gryffon with the roc or rukh, familiar to us through the *Arabian Nights*. 'But this I can tell you for certain, that they are not half lyon half bird, as our stories do relate, but, enormous as they be, they are fashioned just like an eagle.' This bird, however, could lift an elephant in its talons, carry him high into the air and dash him to the ground so that it could devour the flesh at leisure. The spread of its wings was about sixteen paces. Another traveller brings a similar tale of the roc, this time from India, where he 'had seen a certain person who said he had seen one.'

THE UNICORN.—Many and varied are the legends that refer to the unicorn or monoceros—the one-horned. These are crystallized in the figure of the heraldic unicorn which came into general use about the beginning of the seventeenth century. Pliny thus describes it: 'The unicorn has the head of a stag, the feet of an elephant, the tail of a boar, while the rest of its body is like that of a horse; it makes a deep lowing noise, and has a single black horn, which projects from the middle of its forehead, two cubits in length.' Other writers speak of the horn as of ivory whiteness, while one, more credulous, or more imaginative than the rest, describes it as 'outwardly red, inwardly white, and in the middest or secretest part only, black.'

But there was no diversity of opinion as to its virtue. It had power to heal the most deadly diseases; it was an unfailing discoverer of poison as well as an antidote to it. Not only was a unicorn's horn used to test the food offered to kings, but the wild beasts of the wilderness did not

venture to drink of certain pools, for fear of venomous serpents, until the unicorn had stirred up the water with its horn. Widely as the descriptions of the unicorn varied, there were other points, in addition to the possession of the spirally twisted single horn, which were common to them all. The unicorn was very fierce; it was quarrelsome with its own kin, kicking with the heels like a horse but biting like a lion, but it was sometimes friendly to other animals, and always fascinated by a maiden, who alone could tame it; it lived on the desert or on a lonely mountain top, and it could never be taken alive. Moreover, it had no 'articles' (joints) in its legs.

By the middle of the sixteenth century the rhinoceros had been seen and figured, and a writer on heraldry some time later classes it beside the unicorn and says that it is uncertain to which of the two the name unicorn applies, and adds: 'Some hath made doubt whether there be any such beast as this or no. But the great esteem of his Horn (in many places to be seen) may take away that needless scruple.' The horn exhibited in St. Mark's, Venice, is undoubtedly the tusk of the male narwhal, and this is quite clearly seen also from the heraldic figure.

Many monsters are described and figured by the early 'encyclopaedic' naturalists, Gesner and Aldrovandi, which are marine correspondents of animals well known on land. Of the sea-calf, which had the head and voice of a bull, but not its ears, 'because the manner and mansion of its life is in the waters, and such eares would take in much water and hinder it in swimming'; of the terrible sea-pig (*Sus marinus*) with its many eyes; of the sea-horse with its one pair of webbed feet and its long curved swimming tail, and of many wonderful species of whale, accounts will be found in Ashton's *Curious Creatures in Zoology*.

A not unworthy successor of Oannes, the fish-god, was the **monk-fish** or sea-bishop, 'found' in the Firth of Forth in Scotland, and 'seen' off the coasts of Norway as late as the middle of the sixteenth century. It had a human-like head with the mitre of a bishop, and the limbs of a man, but the scale-covered body of a fish. But the sea-bishop was only an outstanding form among many sea-men of less dignified and benevolent aspect. The Norwegian seas seem to have been their chief haunt, and they were believed to steal the fish from the boats and eat them raw. If such a monster was caught upon a hook it was immediately cut loose because of the terrible consequences that would follow the capture. Sudden and violent tempests, from which the fishermen might hardly escape with their lives, would arise from the 'breaking and thickening of the air which the snortling, rushing, and howling of these beasts assembled in an innumerable company causeth.'

There is no doubt that, as the belief in beings compounded of man and fish was one of the earliest legends, so it has been the last to go—

if indeed the **mermaid** superstition does not still linger. The story of sea-maidens with beautiful voices who lured mariners on to the rocks, as did the Sirens and the Lorelei, or of mermaids who came ashore and lived a human life, sometimes, like Undine, gaining a human soul through love and sacrifice, but oftener yielding to their nostalgia for the sea, is used in poetry and imagery again and again. But it was founded on a real and very widespread belief, and many and circumstantial were the accounts brought home by sailors and fishermen of their encounters with such creatures. P. H. Gosse in his *Curiosities of Natural History* (1867) brings together such stories, many of them attested by several witnesses. He is not quite satisfied that the generally accepted explanation that the walrus, seal, or sea-cow, seen with rounded head well out of the water as the mother suckles her young one, is sufficient basis for these stories. Of one of the most circumstantial he writes: ' I do not judge that this single story is a sufficient foundation for believing in the existence of mermaids; but, taken in combination with other statements, it induces a strong suspicion that the northern seas may hold forms of life as yet uncatalogued by science.' An open mind is the true mark of the scientific spirit, but after another half-century of marine investigation we are forced to conclude that the gentle but unbeautiful **dugong** (q.v.) is the only mermaid we are ever likely to know.

It is not surprising that serpents should figure largely in ancient and medieval literature, for they have always had a strong hold on man's imagination, and to write their complete history would be to give an account of some of the strangest beliefs, rites, and customs of mankind. Here they have been worshipped as emblems of the earth's power, there accursed as types of all that is evil; now they are symbols of death, and again of the healing power of the physician; to some they are triumphs of beauty and grace, to others they are repulsive and horrible. Some of the descriptions that have come down to us are very wonderful.

The **basilisk** was a small but terrible creature that moved, not in the usual flowing serpentine fashion, but on eight legs and with head erect. It had a crown on its head, and was ' King of Serpents not for his magnitude or greatnesse, for there be many serpents bigger than he, as there be many four-footed beasts bigger than the lyon, but because of his stately pace and magnanimous mind; for hee creepeth not on the ground like other serpents, but goeth half upright, for which occasion all other serpents avoyde his sight.' Its hiss frightened away all other animals, and its breath was so poisonous that every green thing withered as it passed. So venomous was it, we are told, that when a man slew it with a spear, the poison passed up the shaft and killed not the man only, but his horse also.

The **cockatrice** was another terrible serpent with the same poisonous breath as the basilisk, and the same power of killing the beholder with its gaze. The cockatrice was hatched from an egg laid by an old cock, and, according to the earlier writers, nourished by a toad, but 'by better experience' it was found that the cock himself brooded on the egg. The result was a creature half a foot in length, 'the hinder part like a snake, the former part like a cock because of a treble comb on its forehead.'

The belief in 'winged serpents' or **dragons** was a very ancient one, and it persisted through the Middle Ages, though the animals gradually became less terrible than they were painted in the older legends. The size and colour of dragons differ greatly in different accounts, but the covering of scales, the treble row of teeth in each jaw, and the very bright eyes are very general. They were often associated with precious stones and with treasure-guarding, possibly because of their keenness of vision. Thus Fafnir, the terrible nine-headed dragon whom Sigurd slew, kept guard over the hoarded gold and jewels of the Nibelungs. Later, the dragons which abounded in India carried jewels in their foreheads, as toads also were supposed to do. 'These dragons grow exceeding big, and cast forth from the mouth a most infectious breath, like the thickest smoke rising from fire. These animals come together at the destined time, develop wings, and begin to raise themselves in the air, and then, by the judgment of God, being too heavy, they drop into a certain river which issues from Paradise and perish there. But all the regions round about watch for the time of the dragons, and when they see that one has fallen they wait for seventy days, and then go down and find the bare bones of the dragon, and take the carbuncle which is rooted in the top of his head.'

The fact that the names 'cockatrice,' 'basilisk,' and 'dragon' are used in the Authorized Version of the Bible probably prolonged the belief in their existence. Now the cockatrice has gone, the name basilisk belongs to a lizard of Central America, and the nearest approach to dragons we know anything of are the fossil pterodactyls and the modern flying lizards. But the sea-serpent is with us still! No longer, indeed, do we give credence to tales of sea-serpents two hundred feet long, who hid in holes near the villages of the coast of Norway, and came forth at night to devour cattle and sheep in such numbers that in the morning the shore was strewn with their bones. This particular Norwegian variety was black in colour, and was covered with shining scales; he had shining eyes, and hair a cubit long hanging from his neck like a mane.

Nor can we now take seriously a very circumstantial account of a battle between land-serpents and sea-serpents—an innumerable company of each that took nine days to assemble, and on the tenth

joined in battle from sunrise till sunset, with the result that eight thousand serpents lay dead on the field, and not a single one was left alive.

But right down to our own time there are many well-authenticated records of some great, unknown monster seen in the sea or a lake by travellers, sailors, and fishermen. After every allowance has been made for fraud, superstition, the exaggeration of fear, and mistakes such as taking the individuals of a long chain, e.g. of porpoises, for a continuous line, or a floating mass of seaweeds for a living animal, there remain so many records vouched for by credible witnesses who were familiar with the ordinary phenomena of the sea that it seems wisest to keep an open mind as to what the foundations of such stories may be. Gosse, indeed, had no doubt about the reality of a sea-serpent. After detailing all the more recent stories with the names of the guarantors, he says: 'In conclusion, I express my own confident persuasion that there exists some oceanic animal of immense proportions which has not yet been received into the category of scientific zoology.' In another section of this book we have tried to show how many of the sea-serpents might be accounted for.

THE CROCODILE.—'Sir John Mandeville' writes thus on the crocodile and its tears: 'In this land, and many other places of Inde, are many cocodrilles, that is a manner of long serpents, and on nights they dwell on water, and on dayes they dwell on land and rocks, and they eat not in winter. These serpents sley men and eat them weeping, and they have no tongue.' In another old compilation of beast-lore we are told that if a crocodile meets a man he kills him, but remains inconsolable for the rest of his life. But the general opinion appears to have been that the weeping was a device to attract victims. 'To get a man within his danger he will sob, weep, and sigh as though he were in extremity, but suddenly he destroyeth him.'

The story of the **salamander's** power of living in fire was widely credited, though the more cautious writers only go the length of saying that the beast was so exceeding cold that it put out a fire the moment it entered it. But in a letter supposed to have been written by Prester John to various princes we read: 'In one of our lands, hight Zone, are worms called in our tongue salamanders. These worms can only live in fire, and they build cocoons like silkworms, which are unwound by the ladies of our palace, and spun into cloth and dresses, which are worn by our Exaltedness. These dresses, when we would wash them and clean, are cast into the flames.' Other writers said that asbestos was the wool of the salamander, but Ser Marco Polo robustly declares that salamanders *are* asbestos, and not animals at all, and he gives an account of the finding and using of asbestos, and the cleansing of it by fire when the 'napkins' became soiled. The fire-salamander as we

now know it is nothing more than a harmless newt-like amphibian, six to eight inches long, with irregular blotches of bright orange on its black skin.

Throughout all the old tales, of which the foregoing are only a sample, the almost invariable hostility and harmfulness of the living beast to man is counterbalanced by the medicinal properties of its dead body. Nearly every part, for instance, of a dragon or a crocodile, in powder, pill, or plaster, was reputed to be a certain cure for one or other of the many ills to which man is liable. But it is difficult to find any reason underlying these prescriptions, especially as they were frequently not applied to the affected parts at all, but were worn as amulets, or even packed into a hollow staff, or dropped down a well!

Animals that became extinct within historic times, such as the **Irish elk** and the **aurochs** or **auerochs,** gave rise to many traditions. Aurochs still lived in Britain when Caesar came, and he wrote of them: 'Great is their strength and great their speed; they spare not man nor wild beast on whom they may cast their eyes.' They survived in remote places for some centuries more, and many are the tales of the 'white water-bull' that wallowed alone in the hidden tarns. The ancient Caledonian forest which covered the Vale of Athole was, we are told, famous for 'its dark, intricate windings, its dens of bears, and huge, wild, thick-maned bulls.' The philospher Boëthius thus describes them: 'In the Caledonian forest were sometime white bulls with crisp, curling manes like fierce lions, and though in the remanent of their bodies they seemed meek, they were more wild than any other beasts. . . . They were so wily that they were never taken except by sleight and crafty labour, and so impatient that after they were taken they died of insupportable dolour.'

As the centuries passed Natural History became gradually less superstitious and fanciful, more orderly and precise. The invention of printing spread more accurate knowledge, travel became easier, and travellers less credulous and more observant. The 'encyclopaedic' naturalists of the early part of the seventeenth century amassed great collections of 'facts,' but they took many of them on trust, and they made little attempt to sift or interpret. But in the following century travellers like Thomas Pennant, Peter Pallas, and Alexander von Humboldt not only collected accurate facts about wild animals, but related these wonders to one another, and studied the climatic and geographical conditions of the countries in which they lived.

These naturalist travellers were the forerunners of the greatest of all, Darwin and Wallace, who may be said to have discovered a New World, since they saw it as the outcome of an advance that has been in progress for millions of years. They were the first evolutionist travellers, and they have had many successors whose 'wonders' are

no longer startling surprises, but discoveries that make the world more full of meaning.

THE MIDDLE AGE RELAPSE OF SCIENCE.—There is sometimes a humorous side and sometimes an artistic side to the 'strange animals' which used to be believed in, and their influence still lingers in our midst. But when we come to think of it, much of this fanciful magical Natural History handed on through the Dark Ages is very discreditable to human intelligence. We must separate it entirely from the ancient folk-lore stories of the behaviour of common animals—stories such as we are familiar with in Uncle Remus. For these stories, though unhesitating in reading the man into the beast, often reveal a deep understanding of the animals and a knowledge of their everyday habits. They are sometimes nearer the truth, we think, than the too common modern practice of reading the automatic machine into the beast.

But we are thinking of the heedless and extravagant invention of unreal animals, often with magical properties. This was a symptom of a long discreditable chapter in man's intellectual development.

Some Bible Animals

In considering the animals mentioned in the Old Testament we have to take account not merely of what we know about them to-day, but of what the writers are likely to have known in Biblical times, and also of the state of knowledge at the time of the translation into the Authorized Version. The Biblical writers were speaking of what they had seen, or at any rate of what was well known in their country; but the translators, living in a land where many of the animals did not exist, and at a time when knowledge of other countries was to be found only in ancient writings, or in collections of medieval travellers' tales, must often have been in doubt as to what animal a particular name referred to. Much research has been devoted to clearing up some of the disputed points, and we have taken Canon Tristram's great work on the *Fauna and Flora of Palestine* as authoritative.

The geographical and climatic conditions of Palestine, limited in area though it is, made possible a very varied fauna, representative indeed of several different zoögeographical regions. The country has a very long coast-line on the west, and stretches of desert on the east and south, and it has also one feature peculiar to itself—the Jordan valley and the Dead Sea basin. Throughout the whole course of the Jordan, its valley, bounded on each side by high mountains, descends deeper and deeper till the stream plunges into the Dead Sea, many hundreds of feet below the level of the Mediterranean. This basin has an intense, steamy heat, for the sea has no outlet, and the whole of its surplus water is carried off by evaporation. The actual salt-covered

shores of the Dead Sea are as desolate as its waters are barren, but the Jordan valley and the wadis or rocky gorges among the hills harboured many animals, and gave refuge to many survivors from a time when the general temperature was much higher.

Among such survivors was the **lion**, for, though no lions have lived in Palestine for centuries, there is abundant evidence that they persisted far into the Christian era; and it is apparent, from the frequent mention of them in the Old Testament, that they were well known in ancient days. Thus Samson met a young lion which he 'rent as he would have rent a kid, and he had nothing in his hand.' And David, when a lion attacked his flock, 'caught him by the beard, and smote him, and slew him.' Many other passages refer to the lion, either in imagery or in actual narrative.

The only other member of the feline tribe mentioned in the Old Testament is the **leopard**, and it is often associated in imagery with the lion (Hos. xiii 7; Is. xi 6). Elsewhere, its fierceness, its lurking habits, and its beautiful skin are referred to. The leopard can adapt itself to comparatively cold climates, and it survived in Palestine long after the lion had died out. It is no longer common, but still occurs round the Dead Sea and in some wooded districts. Canon Tristram tells us that during his visit a magnificent pair was shot by Arabs on Mount Carmel.

Of the canine tribe, the **fox**, the **jackal**, and the **wolf** are frequently mentioned, though the first two are not clearly distinguished from each other. A word translated 'wild beast' is also believed to refer to the jackal (Is. xiii 22). The wolf was less abundant, but obviously greatly feared. 'Swifter than leopards, fiercer than evening wolves.' 'Benjamin shall ravin as a wolf.' The dogs that 'go round about the city' and 'wander up and down for meat' were the pariah dogs, that is, domesticated dogs run wild or 'feral,' that were tolerated because of their use as scavengers, and as the best defence against wolves and jackals.

The **bear** is alluded to many times in the Old Testament, and a 'she-bear robbed of her whelps' is a frequent symbol of great fierceness. The Syrian bear, differing only slightly from the brown bear of Europe, is still fairly common, especially in the northern parts of Palestine and about Mount Lebanon, whence, we are told, the Romans drew most of their supplies for the sport of bear-baiting. But from many parts where it was once abundant it has been driven out by persecution, and by the cutting down of the dense growth which filled the ravines.

BEHEMOTH.—The word 'behemoth' is said by Hebrew scholars to be a Hebraized version of an Egyptian one, *p-ehe-mau*, the water-ox. The description was long supposed to be a poetical and general one referring to any large animal, the elephant, the rhinoceros, or

some extinct monster; but greater knowledge of the habits of animals has shown that it refers beyond question in all its details to the **hippopotamus.** The faithfulness of the description is easily realized if we read Professor A. B. Davidson's translation, which is more literal than the Revised Version:

Behold now behemoth
Which I have made with thee ;
He eateth grass as an ox.
Lo! now his strength is in his loins
And his force in the sinews of his belly.
He bendeth his tail like a cedar ;
The muscles of his thighs are knit together ;
His bones are pipes of brass ;
His limbs are like bars of iron.
He is the chief of the ways of God.

. . . . .

He lieth under the lotus trees
In the covert of the reeds and fens,
The lotus trees cover him with their shadow ;
The willows of the brook compass him about.
Behold the stream swelleth, he trembleth not,
He is careless though Jordan break forth upon his mouth.

It is not certain that the hippopotamus lived in Palestine at any time, and it is not now found north of Khartoum. But its bones occur in the delta of the Nile, and from many representations on monuments and frescoes it has been concluded that hunting the hippopotamus with harpoons and snaring it with hooks were favourite sports among Egyptians of high rank. And according to Lydekker, 'it is just possible that the hippopotamus lived in Palestine within historic times.'

THE WILD BOAR.—Though there are many references to swine in the Old Testament, always in terms of detestation (Is. lxv 4; lxvi 17), there is only a single passage in which the wild boar is mentioned: 'The boar out of the wood doth waste it (i.e. the vine), and the wild beast of the field doth devour it.' Many parts of Palestine, especially the valleys of the Jordan and its tributaries, with their jungle-like vegetation and dense thickets of reeds, afford ideal conditions of existence for wild swine, and they are very abundant. They remain hidden by day but emerge at night, and do great damage to crops unless these are well guarded. The watchers have to be very wary, for a fully grown boar with well-developed tusks is no mean adversary. The wild sow, like its domestic relative, is very prolific, and this

quality adds to the difficulty of keeping the numbers down. Fortunately they have many natural enemies, for, in addition to the great carnivores which attack the herds, fox, lynx, and other small beasts of prey levy a constant toll on the piglings.

ASSES AND WILD ASSES.—In all Eastern countries the ass plays a very important part. Those in common use—and even the beggars ride to and from their daily pitch—are only moderately large and slightly built, but they will carry a man for hours under the burning sun. Much more highly prized, however, are the larger, carefully bred and tended silvery-white animals used by the wealthy, and this '**white ass**' is probably referred to in such passages as Judges v 10, 'Speak, ye that ride on white asses, ye that sit in judgment,' and in the vision of Isaiah when he saw 'chariots of camels and chariots of asses.'

But the noble white ass is in its turn far excelled in beauty, swiftness, spirit, and fascination by its more distant relative, the **wild ass.** This fascination the writer of the Book of Job evidently felt when he wrote the lines: 'Who hath sent out the wild ass free, or who hath loosed the bonds of the wild ass, whose house I have made the wilderness, and the barren land his dwelling? He scorneth the crowds in the cities, neither regardeth he the cry of his driver. The range of the mountain is his pasture, and he searcheth after every green thing.' One passage apparently refers to an interesting feature in the life of the wild ass—its annual migration. 'The wild asses did stand in the high places; they snuffed up the wind like dragons; their eyes did fail because there was no grass.'

There are three species of Asiatic wild ass, that referred to in the Old Testament being the Syrian wild ass or **onager** (*Equus onager*). Its range extends from Syria and Persia to India, where it is replaced by the Indian species. The onager, though smaller than the other wild asses, is larger than the domestic ass, with smaller ears and more slender limbs. Its colour is a beautiful silvery white, with a broad dorsal stripe; the lower parts of the body are buff; its coat in winter is thick and woolly, in summer soft and silky. Its senses are so acute and its fleetness so great that it is very difficult to approach, and hunting it has from very early times been regarded as one of the noblest sports of the East. It is occasionally taken alive by means of pits, and such animals are highly valued for improving the domestic breed.

THE CAMEL.—The numerous passages in which the camel is mentioned probably refer to the Arabian or single-humped camel, and the different words used to denote it point to the different breeds, for these may vary as widely as a racer and a cart-horse. Camels seem to have formed a considerable part of the wealth of the pastoral

Hebrews, many of whom owned enormous herds. Part of the gift sent to Esau by Jacob was 'thirty milch-camels with their colts,' and we are told of Job that he possessed three thousand camels, and that this number doubled on the return of his prosperity. (For details of the animal's adaptation to desert life, see CAMEL.)

THE UNICORN.—It has been said that to most readers the passages about the unicorn in the Old Testament at once suggest the heraldic unicorn, and it was precisely this the translators had in mind when they used the word. But we must remember that there was no want of clearness on the part of the original Hebrew writers; they were speaking of an animal they knew, and they described it vividly and accurately. But the translators had no knowledge of it, and to them the Hebrew *re'êm*, with its enormous size, its great strength, its untamableness, and above all its powerful horn—for, for some reason, they took it to be a single one—suggested the mythical unicorn (p. 889); and it is easy enough to see that the emphasis on the horn in Ps. xxii 21 and Ps. xcii 10 would help to mislead them. It was at a much later date that actual specimens of the 'unicorn's horn,' like the one exhibited in St. Mark's, Venice, were shown to be the tusk of the male narwhal (p. 890)—a modification of one of the incisor teeth (see NARWHAL).

An important step was taken when it was shown that the single horn was a mistranslation, and that the marginal reading in Deut. xxxiii 17, 'the horns of an unicorn,' was the correct one. It was further pointed out that the *re'êm* in the Book of Job clearly indicated a member of the ox tribe, for all the work that the unicorn will *not* do is that usually performed in Palestine by the domestic ox.

'Will the unicorn be willing to serve thee or abide by thy crib?'

'Canst thou bind the unicorn with his band in the furrow, or will he harrow the valleys after thee?'

'Wilt thou trust him because his strength is great, or wilt thou leave thy labour to him?'

'Wilt thou believe him that he will bring home thy seed, and gather it into thy barn?

Authorities are now generally agreed that the Hebrew *re'êm* is the aurochs (*Bos primigenius*). Direct evidence of the former presence of this animal in Palestine was furnished by Canon Tristram's discovery of its teeth among the heaps of bones of animals which had been used for human food.

CONEY.—The name coney properly belongs to the rabbit, but there are no rabbits found in Palestine. The coney of the Old Testament was the Syrian *Hyrax*, which is comparatively abundant in many parts of Palestine and 'extremely common in the gorge of the

Kedron, from Marsaba eastward, and all down the west side of the Dead Sea' (see HYRAX).

EAGLES AND VULTURES. — The birds most frequently mentioned in the Old Testament are the eagle and the vulture—'the eagle, the ossifrage, the ospray . . . and the gier-eagle.' The word here rendered 'eagle' may be a general term referring to any of the species occurring in Palestine. Of these the largest is the golden eagle, but it is only a migrant from the more northern regions where it breeds. The smaller imperial eagle is much more abundant. It nests in trees, and the same pair are said to use the same nest year after year.

Very often the word 'eagle' refers to the gryphon or griffon *vulture*, and Canon Tristram tells us that the Hebrew word rendered 'eagle' is identical with the Arab name for the griffon, and that the word translated 'vulture' probably refers to some of the smaller birds of prey. Some of the passages, 'They shall mount up with wings as eagles,' 'An eagle stirreth up her nest,' would apply equally well to either bird, but in others (Job xxxix 27–30; Micah i 16) the vulture is undoubtedly meant. The griffon is very common in Palestine, and colonies of eyries are found in every ravine.

The ossifrage or lammergeier is still larger than the griffon, but it is not so common in Palestine. The ospray, or osprey, as it is now written, is one of the smaller eagles, which lives beside lagoons or at the mouths of rivers and feeds on fish. It is still found on the Syrian coast, but is nowhere abundant. The word rendered 'gier-eagle' is believed to refer to the little vultures known as Pharaoh's chickens, which are tolerated about every Eastern town because of the service they render in clearing up garbage of all sorts from the waste-heaps.

THE STORK.—'The stork in the heaven knoweth her appointed times; and the turtle, and the crane, and the swallow, observe the time of their coming' (Jer. viii 7). It is little wonder that the Hebrew prophet was impressed with the regular arrival and departure of these birds. Even the coming of the smaller migrants can hardly pass unremarked, and the sudden arrival of flocks of great, beautiful, white storks changes the whole aspect of Palestine. Dr. Shaw, a traveller in the early part of last century, tells us that when his vessel anchored under Mount Carmel, he saw three flocks, each of which was half a mile in breadth, and took three hours to pass. Tristram speaks of the storks as arriving in the middle of March, and from then till the middle of May they took possession of the country, especially where there were marshy plains; 'they were equally abundant on both sides of the Jordan.'

THE OSTRICH.—The two chief passages referring to the ostrich (Job xxxix 14–18; Lam. iv 3) emphasize its lack of parental feeling, and its stupidity. Modern knowledge has vindicated the character

of the ostrich as a parent, especially in the case of the male bird, but it only confirms its reputation for lack of understanding, for it loses its head and gets into a panic on the slightest provocation. Ostriches can still claim a place in the fauna of Palestine, for they may be seen on the plains of Moab, though probably only as stragglers from central Arabia.

SERPENTS.—In this case again the word most frequently used is apparently a general term, and it is not often possible to decide which species is meant. But it is clear enough that snakes were regarded by the ancient Hebrews with the same mixture of horror and admiration with which they inspire us to-day. The identity of 'the adder in the path, that biteth at the horse heels' (Gen. xlix 17) admits of little doubt. The reference is to the little *Cerastes* or horned viper, which is fairly common throughout Arabia and Syria. Its habit is to lie half-buried in the sand, or coiled up in a crevice, and wait for its prey; and travellers tell us of the mad terror of their horses when they see one of those deadly little reptiles. In other passages it seems likely that the cobra was referred to. The word 'cockatrice' frequently occurs in our version, and the name is interesting as throwing light on the translators' ideas of serpents; when the passage indicated a particularly venomous creature, the name of the terrible but entirely fabulous cockatrice was given to it.

LEVIATHAN.—In Psalm civ 26 this word is apparently used of some marine monster, possibly a whale, but in the forty-first chapter of Job it undoubtedly refers to the crocodile (q.v.):

> *Who can open the doors of his face?*
> *His teeth are terrible round about. His scales are his pride,*
> *Shut up together as with a close seal.*

But other parts of the description might apply to any terrible monster not very accurately known, and seem to indicate a greater dread than even the crocodile's predatory habits suffice to explain.

There is conclusive evidence to show that the crocodile existed in Palestine till the close of last century, though only in small numbers and in a few localities. Tristram saw the traces of one in the mud of the Zerka valley, and he also secured a specimen measuring eleven feet six inches in length.

Among INSECTS the ant is referred to in Proverbs vi and xxx, with emphasis on her unceasing industry and her foresight in laying up stores—a habit which later researches have abundantly verified (see ANT). Bees are mentioned often, and usually as an image of anger and trouble. This is not surprising, for we are told that wild bees nest so abundantly among the rocks and in the trees of Palestine that some of the narrower gorges are almost impassable because the traveller is

at once pursued by an angry buzzing crowd. But the forests literally drop honey as they did when Jonathan, ignorant of his father's vow, stretched forth his rod and refreshed himself with it.

LOCUSTS.—It is said that several different words are used in the Old Testament to denote either different species of locust, or different stages in the life-history. But we need not concern ourselves with these, for the account (Exod. x) of the plague which befell the Egyptians gives a description, accurate in all its details, of the habits of the common migratory locusts of the East, and for happy imagery and graphic force the beautiful description written by Joel of old still stands unrivalled.

SPIDERS.—'The spider taketh hold with her hands, and is in kings' palaces.' It is generally believed that this passage (Prov. xxx 28) refers not to the spider, but to a member of the lizard tribe; and the word 'lizard' is used in the Revised Version. The description best applies to the **gecko** (q.v.), a harmless lizard common not only on rocks and old walls, but within the houses in Palestine and other warm countries. The plaited toes act like suckers and enable the gecko to run with ease up or down the smoothest wall, or even across a flat ceiling. Two other passages certainly refer to the spider (Job viii 14; Is. lix 5) (see SPIDERS).

Some Odd American Animals

Not uncommon in southern California, especially in sun-baked, arid places, is the horned toad or *Phrynosoma* (see p. 507). It is an easy-going, sun-loving, squat lizard, bristling with peculiarities. Thus it has a collar of sharp spines round its neck, so that it is not likely to get its head bitten off! It is protectively coloured in brown and grey, so that it is very inconspicuous against a background of dry earth. It is an effective burrower, sinking flatly into the ground, so that the last part to be seen is the head, or the ridge of the back, or the ring of spines on the neck. When its head is stroked the Phrynosome sinks into a state of animal hypnosis. When it is teased it sometimes squirts drops of blood out of its congested upper eyelid. A queer creature!

Near Santa Barbara in southern California we saw by the roadside a bird so remarkable that we could scarcely believe our eyes, as people say. It was a cuckoo, and it says 'coo-coo'; yet it was very unlike the British cuckoo and any other species we have seen. It is called the road-runner (*Geococcyx californianus*), and it has taken to the un-cuckoo-like habit of running quickly along the ground. A large greyish bird it is, with a black hood, a tawny breast, and a long tail streaked with white. It is characteristic of dry, cactus-covered places or brushy scrub, where it hunts for insects and occasionally kills a small

bird. It does not fly much, except when hurried or worried, or to clear some obstacle; and its popular name refers to its quondam habit of running ahead of a horse or wagon on the long stretches of brush-bordered trail. But nowadays there are not many horses in southern California (though we saw a horse-show advertised in Los Angeles), and the road-runner does not try to compete with motor cars! When it finds safety after a run, it erects the black feathers of its crest and raises its long narrow tail. When courting it calls 'coo, coo, coo,' or words to that effect; when excited it utters a rattling, 'brr' which is produced by rapidly clicking the lower jaw against the upper.

The road-runner is interesting in its divergent habits, which are associated with some lengthening of the lower leg and some reduction of the wing; and this change must have taken place a long time ago, for it is seen in remains dating from before the later half of the Pleistocene. In the strange La Brea asphalt beds at Los Angeles, in which many creatures were entrapped, there are limb bones of the road-runner, and the beds are believed to have been formed some 100,000 years ago. Miss M. L. Larson has carefully studied these remains, and has found that they are the same as those of the birds living to-day. The bird reached its peculiar climax long ago, and has not appreciably changed since the adaptation was established.

This does not mean that evolutionary change is necessarily slow; it means that when a particular peculiarity suited to the conditions of life has been stabilized, there is no reason to expect that variational departures from the adaptation will take hold. But the stability of the road-runner's skeleton throughout 100,000 years warns us against expecting big structural changes in those parts of man which are satisfactorily adapted to their function. Thus there are more variations in the teeth than in the hand, more variations in the brain than in the eye.

We were interested in seeing a living specimen of the Mexican lizard *Heloderma*, which is unique among lizards in having poison-glands opening at the bases of some of the teeth. The whole body is covered with rounded scales, like the old-fashioned bead-work, and in the living specimen that we saw some areas were of a delicate salmon-pink colour, while the rest was dark brown. Heloderma lives an easy-going life, not exerting itself more than it needs to. Is it dimly aware that it is venomous, or has it simply become so accustomed to being left alone that it is nonchalant about everything?

In the Field Museum in Chicago we saw a magnificent specimen of one of the most remarkable of American fishes, the alligator-gar or bony pike (*Lepidosteus* or *Lepisosteus*), which is characteristic of the swamps and flood-beds of the Mississippi River and of the shores of the Gulf of Mexico (see p. 438). The specimen we saw was about

seven feet in length (much larger ones have been recorded, if not measured), and worthy to be placed beside its companion the alligator. It belongs to a very ancient stock, distantly related to the sturgeons, and is famous for its coat of mail, which consists of irregularly four-sided, interlocked plates of bone, varnished over with a very hard enamel-like material called ganoïn. The armour is so hard that people speak of 'seeing fire fly from the edge of the axe' when they try to chop through the skin of a gar. The creature looks stiff when it is stuffed, or even when it is floating quietly, but its armour is flexible and the body is as sinuous as an eel's. It may lie motionless for hours among the water-weeds, and then make a sudden dash after a fish. As the water in which it lives is often stagnant, the gar does not manage to absorb enough of oxygen through its gills, so it takes gulps of air from the surface into its swim-bladder, which thus does duty as a lung.

The purple eggs are liberated in long ropes of jelly, several inches in diameter, and suggestive of toad's spawn. They are attached to old snags or to trees that have fallen into the water. The young are very voracious, and grow very quickly. They are, to begin with, without the bony plates or the long snout characteristic of the adults, but in front of the mouth there is a patch of suckers by means of which they take hold of objects in the water. The gar is a scavenger, but catches fishes when it can; 'it eats a great deal of food that young fish need'; but its chief economic interest is that it is the temporary bearer of the larval stages of the yellow sand-shell that yields the best mother-of-pearl in the Mississippi region—a good instance of the linkages that make Natural History so fascinating.

DEATH-TRAPS.—The city of Los Angeles, with a population of over a million and a half, extends over an area enormous even in America. It spreads like a gigantic amoeba into the oil-fields and orchards of the adjacent country. On the one side it climbs up the mountains; on the other it insinuates itself over the cliffs and sandy bays of the Pacific sea-front. In ratio of population to square-mileage (over four hundred) it is the largest city in the United States, if not in the world. It must be admitted, however, that the largeness of this sunny city is partly made up by including areas like Pasadena and Long Beach, which call themselves adjacent towns, though Los Angeles likes to regard them as suburbs. Moreover, the spread of the city includes many vacant areas, some to be left as open spaces and others to be speedily filled up as the population continues to increase. One of these unbuilt-on islands in the sea of houses is Rancho La Brea, which has come to have some scientific fame. It consists in part of an oil-field, studded with the usual lofty derricks supporting the pipes into which the precious fluid is pumped, and also

of a park, generously given to the city by Mr. Hancock, which contains the interesting death-traps which we wish to explain.

These consist of basins of asphalt of relatively recent (Pleistocene) age, perhaps 100,000 years old, which have burst to the surface and formed sinister pools of black, gluey, semi-fluid material, often descending to a great depth. Some of them are covered with water, which masks their treacherousness; and we saw patches of floating duckweed flourishing in some corners. Every now and then a huge bubble of gas rises to the surface and makes a spreading eddy. With due precautions it is possible to light this gas and produce a momentary explosion. In some cases minute outbursts of asphalt, not larger than a silver dollar, may be found among the grass of the park, and after they have exploded they show little craters like volcanoes seen from an aëroplane. The origin of the asphalt is probably wrapped up with that of the oil; in other words, it is due to buried and metamorphosed organisms.

It was surprising to us to see no railings round these asphalt pools (though one of them was roofed in) and no warning notice-boards, for the danger to children seemed tragically obvious. Even a light weight, like that of a pigeon, sinks into the gripping ooze, and the frantic struggles soon complete the engulfing. A few instances are on record of rescues at the nick of time, but even a rescue is difficult. The rarity of any accident in recent years seems to indicate a high development of wariness on the part of the Angelian child. As a matter of fact, we saw no children about on either of the two occasions on which we visited the death-traps, and there may be some ban which our unaccustomed eyes failed to detect.

The scientific interest is not far to seek. In bygone days many beasts and birds were entrapped in these asphalt beds, and their skeletons have been well preserved. Some heavy mammals, like elephants and mastodons and ground-sloths, would fall ready victims if they became involved in the yielding asphalt, or ventured into the water to drink. The struggles and perhaps cries of a big pachyderm would attract carnivores, such as the lion-sized sabre-toothed tiger; and these in turn would be caught in the asphalt trap. Others might come for the partially engulfed carrion and add to the list of victims; and that was particularly true of birds of prey, like vultures, eagles, and hawks, whose remains have been found in almost incredible numbers. The bones are not fossilized, but simply impregnated with the preservative asphalt. All horny material, like feathers and scales, has been long since dissolved away, but many of the skeletons are beautifully complete and are displayed with great impressiveness in the Los Angeles County Museum in Exposition Park, where there are well over 100,000 specimens, for the most part judiciously stored

in the cellars. The method of preparation is to immerse the garnered bones, or chunks of asphalt showing hints of bones, in hot kerosene. This dissolves away the matrix and leaves the clean bones, coloured a dark peaty brown by the asphalt. It is a triumph to have built up the skeleton of an elephant, a ground-sloth, a prehistoric horse, a sabre-toothed tiger, a giant vulture, an extinct peacock, and so forth, from the *disjecta membra* dug from the asphalt pits.

The spoils from the death-trap are often very stimulating to the imagination, such as a great heap of canines from *Smilodon*, the sabre-toothed tiger, sometimes projecting six inches beyond the sockets. The skull sometimes shows the milk set and the permanent set both in situ. There were also unborn kittens of the same superlative carnivore. The massive skeleton of the ground-sloth (*Mylodon*) looks as if it had been built for eternity, and yet the animal has passed from the stage. The bony buttons which covered its skin are very common in the beds. Professor Loye Miller has described many of the birds from La Brea, some extinct, like the huge vulture-like *Teratornis*, whose merrythought has span enough to straddle a large human skull, and others represented to-day, like the cuckooish road-runner that does not seem to have changed at all since its ancestors were entrapped in the asphalt beds a hundred thousand years ago. The care with which the remains from La Brea have been scientifically utilized by Professor Loye Miller and others is an object-lesson in the art of making the best of hidden treasure. When we saw elephants and camels, horses and bisons, bears and tigers in the museum, we naturally looked about for remains of man. There indeed he was—a La Brea man, but so like a poor Indian of to-day that we were not surprised to hear the expert say that the skeleton represented an intrusion—we do not say intruder —who had sunk down from the surface into the remains of creatures older than himself.

Treasures of St. Kilda

When the remote island of St. Kilda was surrendered to solitude in 1930, by the transference of the three dozen human inhabitants to the mainland of Scotland, some native (!) animals were left behind. These included the St. Kilda wren, a unique species found on all the islands of the group; the St. Kilda field-mouse (*Apodemus hirtensis*), which occurs on Hirta, Soay, and Dun; and the St. Kilda house-mouse (*Mus muralis*), which used to be confined to the post office of Hirta. Besides these there may be two or three others, almost, if not quite, peculiar to the lone islands; and we cannot forget the interesting, old-fashioned, half-wild sheep of Soay, whose origin seems to be hidden in the mist.

Why should a remote island have a wren or a field-mouse all to

itself? Why is there an Orkney vole and a Fair Isle mouse? The answer seems to be that these insular species are derived from immigrants from the mainland, belonging to the species of common wren and common field-mouse; and that these immigrants varied, as many animals are always doing, and as children in a human family so often illustrate. New departures or individualities emerge from the germinal fountain of change, and if these new departures (variations or mutations) are not disadvantageous, or are in some little way advantageous, and if they find others like themselves to pair with, they will form a new sub-species or species which may supplant or exist alongside of the original stock. The reason for the not infrequent occurrence of these unique species on islands is simply that insulation or isolation lessens the range of intercrossing, and brings similar forms together as parents. In the famous case of the Galapagos Islands there are seven different species of giant tortoise now isolated on seven different islands of the archipelago, each island with its own treasure, except that the largest island, Albemarle, contains five species. The explanation must be that a great peninsula with one species of giant tortoise was submerged so that its volcanic peaks formed an archipelago, and that in the course of time, as variation continued and isolation persisted, many true-breeding distinct species arose on the various islands. Little can we wonder at young Darwin's exclamation at Galapagos, that he felt himself 'brought near to the very act of creation.' Scores of similar instances of peculiar species on islands are so cogent that we can understand why Darwin in later years dropped the word *creation* (from the biological dictionary) and substituted the word *evolution*. It will be understood, of course, that if the word 'creation' is used to mean 'the emergence of the new' or 'the Divine ordering of Nature by which the process of evolution came and comes about,' no scientific investigator has, as such, any objection to offer.

We are getting a little far from the remote St. Kilda, but we take this opportunity of saying that no naturalist supposes that a mainland field-mouse turns into a St. Kilda field-mouse. That would be magic, not evolution. What happens is that in the course of generations novel variations crop up in the successive families, and it is the survival and success of these divergent variants that result in new species which may exist alongside of their originative stock.

There is no particular difficulty in the question of the original arrival of the immigrants. The mice and voles might come as stowaways on board fishing-smacks or the like, and the little wren can fly far. In the case of the Galapagos Archipelago, the non-swimming giant tortoises found themselves marooned by some geological change.

The Seven Wonders of Life

No doubt there are a thousand wonders of life, but there are seven outstanding. But what, to begin with, is a wonder? It is not merely something startling, or surprising, or upsetting, or enormous; it is something a knowledge of which makes everything else deeper or higher or more full of meaning.

The first wonder is the omnipresence of **beauty**—apart, of course, from mongrelized or artificially degraded man, and from the marks of his fingers upon life, as in prize pigs and buxom cabbages. Our proposition is that all full-grown, free-living, healthy living creatures are beautiful, in their natural surroundings at least. Thus a jellyfish must be seen throbbing in the tide, and a hippopotamus among the reeds and willows. 'Beauty' is that quality which excites in us the aesthetic emotion: 'a thing of beauty' is best defined as 'a joy for ever.' But it has also an objective basis; it is the expression of a harmonious way of living, of a time-tested constitution from which all that ever approached the discordant has been eliminated.

No doubt some creatures are more beautiful than others, for Walt Whitman was wrong in saying that 'all are equally perfect'; and some types of beauty, such as that of the snake and the octopus, are more difficult than others, just as with pictures. Meredith hit the nail on the head with his remark: 'Ugly is only half-way to a thing'; and while Nature never stops there, it has not always had time to give the touch of perfection to its evolutions.

There is a quality of **unconquerableness** about many creatures. One of our British starfishes has 200,000,000 eggs in a year. There are far over a quarter of a million different kinds of insects. A big tree recently cut down had wood-rings which showed that it was a seedling before Christ came. The Pacific golden plover winters in the Sandwich Islands and nests in distant Alaska; on its return journey, at least, it seems to fly without any rest for 2,000 miles across the pathless sea. Terns taken on board ship in closed baskets into unknown waters are sometimes able to return to their nests from a distance of 800 miles.

There is no haunt where the voice of life is not heard, not even the great abysses with their eternal winter and eternal night. Except for a minority of shirkers, like those that enter the open door of parasitism, animals have grit, and plants their patient tenacity.

Choose any animal you like, a mole to-day and a whale to-morrow, and you find it a bundle of **fitnesses.** If you take away from a bird all its adaptations, is there anything left? As the poet said: 'The narrowest hinge in my hand puts to scorn all machinery.' The majority of flowering plants have their pollen-dusting insect-visitors, and they suit

one another as glove fits hand, yet far more subtly. Such a vegetable carnivore as Venus's fly-trap takes one's breath away with the finish of its vital contrivances for catching its booty.

A whirligig-beetle gyrating on the surface of a pond is greater than any star, inasmuch as it commands its course. Living creatures always hold in their hands, so to speak, the bent bow of endeavour. Even when they do not know what they are doing, they are **purposive.** The gull lets the mussel fall from its beak on the rocks below; the water-spider, though belonging to a terrestrial race and breathing dry air, weaves a sub-aquatic nest in which she lays her eggs and brings up her young; a collie dog manages its sheep with intelligence, and an anthropoid ape puts two sticks together to make one long enough to retrieve the fruit outside the bars of its cage.

At many different levels—reflex, tropistic, instinctive, intelligent —there is effective behaviour among animals; and some plants show the first stirrings of organic memory.

Only in the world of life is there **a sequence of generations** and only in the world of life are there individuals that climb the genealogical tree of their race. The eggs of the frog develop in three months or so into froglings that must get out of the water or drown; and the many circuitous changes in the story of the tadpole are only intelligible in the light of the dim and distant past, when, in late Devonian Ages, Amphibians evolved from a race of pioneering fishes.

The life-story of such common fishes as salmon and eel reads like a romance, as in a way it is. A may-fly may have an aquatic larval period of three or four years and perhaps one evening of adult aërial life, when hunger ceases and love has its dance of death. Into the life-histories of animals the angels might well desire to look.

Darwin with his characteristic shrewdness recognized that '**success in leaving progeny** ' was just as important as bread-and-butter, and counted equally in the struggle for existence. One solution is spawning, and this holds for many, such as the fishes that would soon make the sea solid if it were not for the ceaseless reincarnation. The other solution is parental care, and at how many different levels, from the brook-leech that carries its young ones about on the under-surface of its body to that long-tailed tit that gathered 2,379 feathers to make a quilted nest, and on to some mammals which will face death in defence of their offspring.

The crowning wonder of life is **Evolution.** For several hundreds of millions of years life has been slowly creeping, sometimes swiftly leaping upwards, in an unexhausted wealth of forms and subtlety of conquest. No doubt there have been some retrogressions and blind alleys and puzzling circlings, but on the whole evolution has been

progressive. There has been an emergence of finer and nobler forms, and in the animal world a movement towards more mind and towards modes of life that are increasingly satisfactions in themselves. And this evolution is still going on.

Animal Sanctuaries: Natural and Artificial

To the north of Lake Tanganyika in eastern Equatorial Africa there is a strange land of craters, large and small; and one of these craters, called Ngorongoro, is perhaps the most remarkable natural sanctuary in the world. It has been described by Mr. T. Alexander Barns in a fascinating book, *Across the Great Craterland to the Congo* (1923), and it lives in our dreams. Ngorongoro, the greatest crater in the world, is twelve by eleven miles in diameter, whereas Etna is about a mile across and Vesuvius less than half as much. Ngorongoro is surrounded by steep walls from 1,700 to 2,000 feet high, forming a ring-fence which the larger animals do not seem to cross. On the floor of the crater is a blue and bitter lake about four miles long, and all the rest is covered with luxuriant vegetation. The nature of this vast crater has been discussed by Professor J. W. Gregory of Glasgow, who puts it in its proper place. It cannot be an *upbuilt* crater like Etna or Vesuvius, nor an *explosion* crater like Krakatoa in 1883, nor an *erosion* crater excavated on a volcanic mountain by streams of water, aided by rain and wind, or by the sea, nor, of course, an *impact* crater punched in the earth's crust by the fall of a colossal meteorite. It must be a *subsidence*-crater due to a sinking of the ground, after the fashion of the great cauldrons seen in the islands of La Palma and Grand Canary. That the great pits were formed by subsidence is borne out by their shape, structure, and position.

But we are concerned here not so much with the vast cauldron of Ngorongoro as with its contents, which include a resident population of over 50,000 head of big game. From the vantage-ground of a height the explorers looked down on the great crater, twelve miles across, about thirty-five miles in circumference, walled in by an unbroken ring of precipitous cliffs. Where the lava once seethed there was a luxuriance of forest and grass; where the volcano once belched there lay the Magad Lake, blue and gleaming amid its marshes and mud-flats; where a heavy curtain of dust once hung there was a play of miniature rainstorms chasing one another around the rampart of cliffs. And when the observers descended and began to traverse the vast amphitheatre they walked for two hours through mixed herds of big game—wildebeest, hartebeest, zebra, and gazelle. 'Wherever one looked over the far crater-plain there were animals, and, looking at them along an absolutely flat surface, they might well be described

as a sea of backs with an undercurrent of legs as they moved hither and thither about us.'

Besides the four mammals we have mentioned, there were hippopotamuses wallowing in the pools of the marsh, and a rhinoceros lay down in the grass and fell asleep 200 yards from the camp. There were ox-like elands and other kinds of antelopes; troops of baboons moved about unconcerned; and on the mountains outside the ramparts there were family parties of tousle-headed gorillas. Birds were represented by wintering storks and cranes, by ducks and geese on the marsh, by ostriches and giant bustards, guinea-fowl and quickly running quails. The seamy side of the earthly paradise was the presence of lions and leopards, hyaenas and jackals, in great numbers, and very tame. It was easy to understand where the carnivores got their food amid such multitudes of herbivorous creatures, and the sustenance of the latter was obvious in the exuberant vegetation. 'The pasture is practically composed of one close mat of succulent white and red clover, in places growing to such luxuriance on the rich volcanic mud and débris that acres and acres of it stand knee-deep in one solid mass of green.' Here, then, is one of the natural sanctuaries of the world, in which a balance has been arrived at and extermination has ceased. Ngorongoro should be made a reservation area for tropical life.

This long-lasting natural sanctuary, with abundance of life in a balanced give-and-take, makes one think of the possibilities of artificial sanctuaries in a country like Britain, and even in America and in South Africa where large reservations are happily doing much to check extermination. But let us think of a small country like Scotland. Many of our animals are dwindling rapidly in numbers; the quality of wild life in Britain is diminishing. The first question is whether it might not be most useful to purchase several reservation areas at strategic places that are well suited for the conservation of particular types. What would suit a wild cat would not assist the reinstating of the booming bittern. Already there are several well-watched sanctuaries, and we believe that they have abundantly rewarded their founders.

But there is something very attractive in the picture of a spacious sanctuary, perhaps an island, where the animals could be left to some extent to work out their own balance in part of the territory, while in other parts protection would be afforded to those not very able to hold their own in open competition. It would not be very difficult to arrange enclosures with high wired fences well screened with climbing plants, yet so adjusted at the top that the network could not be surmounted. It would also be necessary to extend the netting far into the ground so that the entrance or exit of burrowers would be balked.

An island with diversified relief, with hill and dale, moorland and marsh, lakelet and river, like a miniature Arran, would make a suitable sanctuary; and it should be neither too accessible nor too remote. It would be unnecessary to introduce animals that are still abundant elsewhere in Britain, but one would like to see the beaver, for instance, reinstated, as it was for many years in Bute. Perhaps it would be impracticable to have reindeer and wolf brought back to Scotia Rediviva, but one might perhaps recall the lemming. Of course there would be a strict exclusion of recent aliens like the rats and musquash.

We should not like to risk, except in well-fenced enclosures, the brown bear or the wild boar, but there is no reason why there should not be enough badgers to allow of one being occasionally seen by someone besides Mr. Tregarthen. Lynxes would be rather risky at first, but there should be no difficulty with wild cat and marten. Some primitive domestic animals, like the old-fashioned sheep of Soay and Shetland, would be very interesting, besides shelties and the ponies of Mull. It would be well to leave paths to be gradually evolved, so that they should come to include vantage-points from which certain sights could be seen with ordinary good luck; and naturalists would, of course, be allowed to spend a night on the island.

If shooting were strictly prohibited and some encouragements offered, there would be no difficulty with the migratory birds, and it might be possible, as the good news spread, to induce some of those of long ago, such as bittern and great bustard, osprey and raven, to come back to old haunts. If the sanctuary was an island, the shores would be sacred to seals, and it would be a pious pleasure to stock all suitable places with rare plants like *Primula scotica* and *Linnaea borealis*, and any other treasures that we seem likely to lose for ever. By working cautiously and by anticipating errors it should be possible to evolve a living museum for the conservation of dwindling life, a place where W. H. Hudson's Rima would be at home!

CHAPTER V

SOME PHYSIOLOGICAL ASPECTS OF ANIMAL LIFE

The chemistry of the body—The vital value of water—The sources of energy—Uses of food—Milk as an example of a foodstuff—Animal heat—Hormones—Animal ferments or enzymes—Size and its limits—Animal pigments—Waste-products—Animal sleep.

[N.B.—Since much of the detailed physiology of animal life has been dealt with in the different sections of our survey of the animal world, we shall here describe only a few particular aspects.]

THE CHEMISTRY OF THE BODY

BIOLOGY is the study of living creatures, but it cannot go far without chemistry and physics, for living creatures are embodiments of matter and energy. At the time of the French Revolution, the 'Reds' killed the great chemist Lavoisier, crying in their madness that 'the Republic has no need of men of science.' Lavoisier is memorable for much, and for this not least: that he made one of the bedrock contributions of chemistry to biology in showing that, from a chemical point of view, living always means burning.

Another bedrock contribution was made half a century later by Liebig, always remembered in connection with 'beef-tea'—one of his least important achievements—who grasped the idea of the circulation of matter, which means that the different kinds of material are always passing from one collocation to another. Molecules and atoms are always finding their way from linkage to linkage. Nothing is ever lost, but there is a ceaseless dance in which the elements change partners.

In some cases the chemist has helped the biologist much more than was realized at the time. Thus, rather more than a century ago it was generally believed that a clear line could be drawn between the *organic* substances which plants and animals make, such as sugar and starch, fat and white of egg, and *inorganic* substances which occur in non-living Nature, such as salt and saltpetre. But, in 1828, Wöhler built up urea from simpler materials, and since urea is a characteristic organic substance, formed as a waste-product in higher animals, the chemical wall between the inorganic and the organic showed signs of cracking. But this was the beginning of the long series of achievements by which the chemist, almost like a creator, has built up new things out of old, and has effected the **artificial synthesis** of sugars and alcohols, of indigo and

madder, and of such subtle organic products as the powerful hormones known as adrenalin and thyroxin, the chemical messengers that pass into the blood from the ductless glands called respectively the supra-renal and the thyroid. What is more, it became plain that the organic compounds implicated in the life of the body could no longer form a preserve for the physiologist, but must be tackled by the chemist just like the inorganic earths and minerals.

One of the greatest initiators was Pasteur chemist rather than biologist, who advanced from the technical study of tartrates to a recognition of the manifold activities of bacteria, which have so much significance to the biologist, and to a prevision of the rôle that **ferments or enzymes** play in the everyday life of the body, both of plants and animals. Without some knowledge of ferments we cannot begin to understand the rapidity and the tirelessness of those vital changes that are summed up in the word **metabolism**—the ceaseless downbreaking and upbuilding that is implied in all living.

If one were asked to select a couple of fundamental problems that would illustrate how indispensable the chemist is to the biologist, one could hardly do better than to take (1) the photosynthesis that goes on in the sunlit green leaf, and (2) the properties of colloidal matter.

(1) About 1774 Priestley showed that air 'spoilt' by mice could be made good by green plants, and this was the chemical beginning of the inquiry into the most important process in the world—the process by which the reddish rays of sunlight absorbed by the leaf's sensitizing pigment-screen afford energy to bring about the reduction of carbon dioxide, the liberation of oxygen as a priceless by-product, and the upbuilding of sugar, starch, and other complex carbon-compounds.

(2) Our second example concerns the properties of matter in a **colloidal state**, which began to be studied by Graham in 1861. It is not too much to say that we cannot begin to understand the life of a cell until we know a good deal about colloids. In a colloid there are innumerable ultra-microscopic particles or droplets in suspension or dispersion in a medium, usually liquid, and this multitudinousness provides a very large surface on which chemical and physical actions can take place between the particles or droplets on the one hand and the medium on the other. On this fact many of the things which happen in a living cell are dependent.

One of the milestones of recent advance bears the inscription **glutathione**, which is the name of a widespread organic substance discovered by Sir Frederick Gowland Hopkins in 1921. Its importance is that it acts as an 'oxygen-transporter' between the external oxygen-supply and the combustible material in the tissues. Its discovery helps towards an understanding of the difficult fact that very rapid oxidations in the living cell take place at a low temperature.

There is no possibility of coming near an understanding of the familiar process of **muscle-contraction** unless we take account of the recent chemical contributions, beginning with what was shown by Fletcher and Hopkins, that the stimulation of the muscle brings about the liberation of lactic acid, and that this provokes a physical change culminating in the contraction of the muscle-fibre. Meanwhile, some of the lactic acid is utilized to supply enough energy to reinstate the bulk of it in the muscle-fibre, which thus becomes once more efficient.

Even in embryology the chemist helps. Thus we know that a little butyric acid, which may be readily formed in the body, brings about strange monstrosities. Again, in regard to the evolution theory, the chemist tells us of the subtle chemical differences between, let us say, one kind of grape and another, showing that there is *a chemical basis for species*. Even in Natural History the chemist helps, telling us, for instance, the nature and origin of the body-pigments which are occasionally of life-saving value in camouflaging an animal or advertising a flower.

There is a chemistry and there is a physics of the living creature, but if you add them together you do not get biology. For the living creature is an individuality, an agent that does things, a unity which has, often at least, a mind of its own. We cannot give a chemical account of behaviour or development or evolution. There is a chemistry of the organism, but the organism transcends chemistry.

THE VITAL VALUE OF WATER.—As far as life is concerned, the **circulation of water** is one of the fundamental facts, though few people ever give it a thought. It is almost as basal as our income of light and heat from the sun; it makes living matter possible; and it has its part to play in the building-up of foodstuffs by green plants—the process of **photosynthesis** (q.v.) on which the maintenance of life depends.

As living matter or **protoplasm** does not contain less than 70 per cent of water, and often more, and as living creatures are, as it were, changeful whirlpools in which water delays for a little and then hurries on, Animate Nature depends on the water-circulation. It follows, as a corollary, that there is no use in speculating over the presence of life on any planet where water is not present in liquid form. Man's imagination does not rise to picturing any kind of embodied life radically different from the protoplasmic plants and animals that we know; and these cannot continue living in any place where there is not water in liquid form.

The same indispensability obtains, of course, in regard to all of the 'Big Four' elements, **carbon, hydrogen, oxygen,** and **nitrogen.** It is a waste of time to speculate about the possible existence of embodied living creatures that are not built up of proteins, carbohydrates, fats, water, and salts, as are all the living creatures that

we know. No other kind of creature has ever been concretely imagined.

In winter in the northern regions the circulation of water is characteristically slowed down. There is, indeed, an abundance of water in snow-fields, in glaciers, in frozen streams and ponds, in the bogs, and in the cold soil, but it is only to a slight extent mobilized.

One of the big facts of spring is the recommencement or the quickening of the circulation of water. Under the influence of the sunshine the molecules of water shake off the linkages of the fluid state, and pass freely in vaporous form into the air. The mist, we say, rises from the deep, and clouds are formed. In currents of air these drift across the sky, and are condensed as raindrops on the cold surface of the mountains. The runlets form streamlets, and these become rivers; and so the water comes back to the sea.

Of course there are all sorts of delays in the circulation. The water-vapour in the air may take the form of snow or hail; the trickling water on the rocks may be imprisoned in solid form in icicles; the absorbent bog-moss may capture the water and retain it for many months, keeping the springs welling and the streams flowing through prolonged periods of drought; the animal drinks the water and soon loses it again in the vapour of its hot breath or in the sweat and waste of its body; or the water may be locked up for many years as part of the molecules of complex organic compounds. Sooner or later, and at death eventually, the water sets off again on its endless journey.

How true was the well-known saying of 'the weeping philosopher' Heraclitus: *All things flow.* As a matter of fact, however, Heraclitus seems to have thought more of the endless changes of a universal fire-spirit—the transformations of energy rather than the transformations of matter. But now we know that this is more of a distinction than a difference! In any case, the modern picture is an unending, though often long-resting, circulation of water from one linkage to another all the world over.

Water is the best of all **solvents**; it can dissolve more substances than any other liquid. It is generally accompanied by carbonic acid, which enhances its solvent action. Its capacity for mobilization depends largely on the readiness with which its vapour tension varies with the temperature. Hence the ease of evaporation on the one hand, and of the precipitation of rain and dew on the other. 'Its surface tension, which is greater than that of any other common liquid except mercury, causes water to remain in the soil or wherever capillary phenomena are possible, and thus prolongs the action of water as a solvent.' Water makes the mountains flow down into the sea; and it makes the world of life go round.

Moreover, fresh water is almost unique in expanding near the freezing-point,[1] a property that brings the colder water to the surface of the pool in winter, where it forms a protective sheet of ice (cf. p. 876). This is of great importance in the conservation of aquatic living creatures in northern countries, and it may have been of critical importance at certain junctures in Organic Evolution, as in the emergence of Amphibians some hundreds of millions of years ago.

The best scientific eulogy of water has been given by one of the acutest of the scientific investigators of to-day, Professor L. J. Henderson. It will be found in his *Fitness of the Environment* and his *Order of Nature*, and it forms a strong argument in support of the view that Nature is Nature for a purpose. Let us hear Professor Henderson:

'This water cycle regulates the temperature of the globe more perfectly than it could be regulated by any other substance. It produces an almost constant temperature in the ocean, as well as constancy of composition and of alkalinity. It mobilizes all over the earth great quantities of all the elements; it deposits them in great variety and in inexhaustible profusion in the ocean; it comminutes and disperses all varieties of insoluble minerals, thereby diversifying the land; it causes water to penetrate and to remain in nearly all localities.'

This is a little part of the eulogy, but it is enough to make us think as hard as we can over the way in which the properties of water have worked together to give living creatures a cradle and a home. Every mundane thing depends on water, and even the embodied mind has its haunts in an aqueous medium.

THE SOURCES OF ENERGY.—The great source of energy in the animal body, as in many of the machines invented by man, is the **oxidation** or burning of carbon and hydrogen. Pure carbon burns, and yields energy; pure hydrogen also burns and yields energy—the heat of the oxyhydrogen flame is well known. A fuel such as petrol or paraffin contains carbon and hydrogen, and burns fiercely in air or oxygen till all the carbon and all the hydrogen atoms are combined with oxygen to form carbon dioxide and water; and the energy yielded in this burning is occasionally *greater* than that yielded by the burning of an equivalent number of atoms of pure carbon and pure hydrogen. There is in such a fuel an additional store of energy, bound up somehow in the architecture of its molecules, and set free during the burning to add its quota to the energy generated by the oxidation of the individual atoms.

The **foodstuffs of animals** differ from these typical fuels in that their molecules contain not only carbon and hydrogen but also oxygen

[1] It reaches its maximum density at 4° C.

—sometimes other elements as well. But the presence of oxygen means that these substances are already partially oxidized, half-burnt, so to speak, and consequently have not so much energy to yield by burning as the fuels have. Nevertheless, they are valuable as sources of energy firstly and principally because they can still burn, still combine with oxygen, and set free much energy in the process. They may also contain energy of structure, energy set free when their molecules collapse, just as certain fuels do. Now when a complex organic molecule breaks down, either in the body or in a flame, it is not instantaneously shattered into a cloud of fragments; it breaks down step by step. The house is demolished stone by stone, not blown sky-high. In a flame, however, and still more in an explosion, the various steps succeed each other so rapidly, the intermediate stages exist for so short a time, that it is very difficult to trace the system on which the molecule is broken down or to identify the intermediate stages; in spite of the other complications, it is easier to do this in the animal body, where the whole process is much slower.

It is well to distinguish two distinct ways in which the complex molecule of a foodstuff may be split in two. In the first place, the foods as we eat them are usually enormously complicated, and have to be simplified greatly, by repeated divisions of the molecules, before they can be taken from the alimentary canal into the body itself. Thus starch is split, step by step, again and again, into a sugar (maltose); the last step is the splitting of maltose (malt-sugar) into two molecules of glucose. Now it is characteristic of these simplifying processes that go on in digestion that they are not of a very drastic nature; at each step the new product is chemically rather like the old, as glucose is like malt-sugar. Moreover, at each splitting the broken ends of the molecule are patched; when malt-sugar splits in two, a molecule of water is also split, and the oxygen and hydrogen atoms of the water are added to the halves of the malt-sugar to form glucose; such a reaction—a 'splitting with the help of water'—is known as **hydrolysis.** For our present purpose, the most significant thing about hydrolyses is that, in most circumstances, they yield a little energy (so that it costs the body nothing to simplify its foods, in this sense), but not too much energy, which is well, because energy set free in the alimentary canal would not be of much use to the body, and also because the body has to build for itself similar complex substances for processes of growth and repair.

But after the foodstuffs, simplified by digestion with its long series of hydrolyses, are absorbed into the body, they must, if it is their fate to be burned, be split again, once or many times. These later splittings are of a different type; they are comparable to the hardly traceable splittings of a molecule of benzene in the cylinder of a motor car

(hydrolysis plays no part in the break-down of fuels); they may take place either in the moment of burning, or long before it. They differ from hydrolyses in three great ways; thus (*a*) the products may not be chemically similar to the original substance, glucose for instance splitting into two molecules of the quite dissimilar lactic acid; (*b*) there is no patching of the ends, no intervention of water in the process; finally, (*c*) they set free a great deal of energy, when compared with hydrolyses.

We may compare the molecules of the foods as we swallow them to large, jointed structures, made up of many, generally similar, parts temporarily fixed together. In digestion the molecules are unbuilt piece by piece, with small loss of energy, into their component parts; after absorption, the parts themselves are broken into two or into many fragments, and much more energy is set free; finally, in the ordinary course of events, the fragments are burned. The complex molecules themselves are built up by the green plants, which by virtue of their greenness are able to capture the energy streaming upon them from the sun and to use it to build up complex organic substances from carbon dioxide and water. But although this synthetic process is so conspicuous and so important, yet plants live as animals do, breaking down and oxidizing these molecules and deriving energy from the process; only, in the sunlight, the building-up so greatly preponderates that the excess production of complex substances supplies not only the plant, but the needs of the whole animal world, directly or indirectly.

USES OF FOOD.—It is easy to say that the use of food is to satisfy hunger, but it is necessary to explain why this appetite should be in most cases of survival value. We say 'in most cases,' for many organisms remain alive for long periods without showing any appetite or without taking any food, as in the case of threadworms lying latent, or such hibernating mammals as the hedgehog. In many cases, moreover, the feeding is very passive, as in those corals that mainly depend on the carbon-compounds made by their symbiotic algae.

In most cases, however, hunger is obvious, and we ask what are the uses of food that have made the appetite so general among animals. The answer is manifold:

(1) Food supplies the chemical energy which is turned into other forms when the organisms do work.

(2) Food supplies the material for further growth.

(3) Food is used to equip the egg-cells or the reproductive units with a legacy of nutrition until the young ones are able to feed for themselves.

(4) Food is used as material to replace lost parts or to recuperate everyday wear and tear.

(5) Food is used as a store for seasons when it is not readily procurable.

MILK AS AN EXAMPLE OF A FOODSTUFF.—We have already referred to milk as an important supply of energy (see MAMMALS).

Milk contains proteins, carbohydrates, fats, mineral salts, and water; and every one knows that animals and children can live for a long time on milk alone. It is an almost perfect food—our first and often our last meal. But if we make an artificial milk by mixing in proper proportion the five substances mentioned above, and try to feed mice on it, they will die in a month, as Lunin showed nearly fifty years ago. Part of the difference between the artificial milk and the natural milk is that minute quantities of **vitamins** or **accessory food factors** are present in the latter and absent from the former.

Three hundred years ago John Woodall expounded the efficacy of lemon juice as a preventive of scurvy among sailors, and we now express this fact by saying that the once common scourge is a **deficiency disease** due to the absence of some vitamin from the dietary. But it was not till 1912 that there came the first clear-cut and definite proof of the existence of 'vitamins,' afforded by the experiments of Sir Frederick Gowland Hopkins, the distinguished Professor of Biochemistry in the University of Cambridge.

Analogies never fit beyond a certain point, but Mr. John Pryde, in his *ABC of Vitamins*, uses an effective one in comparing our body to a motor engine. The petrol fuel corresponds to the proteins, carbohydrates, and fat forming the bulk of our food, and required as a source of energy for doing work, to repair wear and tear, and as material for growth. But lubricating oil is also necessary, and in the case of the human engine there are several different 'oils,' which are nowadays called vitamins or accessory food factors. They are definite chemical substances, just as proteins are; but, since they have proved extremely difficult to obtain in a perfectly pure state, their chemical constitution is still uncertain. They can, however, be extracted and concentrated, and are found to be remarkably potent. It is one of their peculiarities that a very small quantity goes a very long way, and that a large amount is no more useful to an animal or a man than a small amount.

Their origin is to be found in plants, but they may be embodied in several different animals before they become part of man's food. Thus the valuable vitamin of cod-liver and halibut-liver oil may come from large carnivorous whelks, which get it from sea-worms, which get it at its source—namely, the minute floating Algae of the sea. Plants make the original vitamins, but there may be chemical transformations of these in the course of the successive reincarnations which form nutritive chains in Nature. When man eats certain vegetables and fruits, he is getting his vitamins at the fountain-head.

Up to the present time, six or more kinds of vitamins have been discovered. We cannot do more here than sum them up. (1) Vita-

min A, soluble in fat, occurs in liver, oils, butter, yolk of egg, and many vegetables. It is a growth-promoter, and essential to young creatures. (2) Vitamin B1, soluble in water, occurs in cereals, nuts, tomatoes, many vegetables, yeast, yolk of egg, liver, brain, kidneys, and sweetbread. It works against certain nervous disturbances. (3) Vitamin B2, a companion of B1, works against the serious disease of pellagra, which is common among maize-eating peoples; and it is also a growth-promoter, though with an influence different from that of Vitamin A. (4) Vitamin C, soluble in water, is present in most fresh fruits and vegetables, from grape-fruit and oranges to potatoes and cabbage. It works against such diseases as scurvy, and is positively essential to our health at all ages. (5) Vitamin D, fat-soluble, is a companion of Vitamin A, and like it has a peculiar importance for young creatures, whether calves or babies. It operates against **rickets**—a children's disease engendered by darkness and wrong dieting. More light and more cod- or halibut-liver oil are at present working what used to be called miracles among poor children. (6) The sixth known vitamin is a fat-soluble 'essence,' found in certain vegetables like lettuce, and in some vegetable oils, such as that formed in sprouting wheat. It seems to be a counteractive of sterility.

As our forefathers, in spite of scurvy and the like, got on not so badly without troubling about vitamins, we cannot miss the practical common-sense corollary that our daily bread should include reasonably heterogeneous unsophisticated natural ingredients. But let us not forget that 'the life is more than meat.' We may suffer from deficiency in our mental as well as in our bodily diet. The oil of liver may be fundamental, but the oil of joy is supreme.

Animal Heat

Every one is familiar with the warmth of the body, which physiologists call 'animal heat.' In cold weather we feel it very pleasantly when we put our hands on a cow's neck, or when we lift a biggish bird like a duck. We enjoy the warmth of our own body when it does not go too far, but we may say at once that its use is much more than making us comfortable; it makes the vital chemical processes go on *quickly and smoothly*.

To some extent heat is produced by many of the chemical changes that go on in the body, and one of the discoveries of Professor A. V. Hill and his fellow-workers is that a demonstrable quantity of heat is given off in a **nervous impulse**, that is to say, in the thrill that passes along a nerve. Thus it is not surprising to find that the most intensely alive of all living creatures, namely the birds, have also the highest temperature.

Birds are from two to fourteen Fahrenheit degrees warmer than mammals; a finch on the hedge may be several degrees warmer than man. The cow is one of the warmest of mammals, and some of the bats in summer come a good second to birds. In a general way it may be said that the temperature of a backboned animal is an index to the intensity of the chemical routine or metabolism, but for practical purposes the muscles produce most of the animal heat. When it is very cold we run about, we stamp with our feet, we clap our hands, or we violently strike the sides of our body with our arms; and these common experiences point to the scientific conclusion that the muscles are the main producers of animal heat. They have what is called a **thermogenic function.**

It used to be thought that heat was produced by the contraction of the muscle-fibres, when they became shorter and broader and did work. Research has shown, however, that heat is apparently not produced in the ordinary actual contraction, a somewhat mysterious physical process, comparable to what happens when a compressed spiral spring is released; though while the released spring becomes longer, the stimulated muscle becomes shorter. The heat is mainly produced by a combustion (of lactic acid) that follows the actual contraction and enables the muscle to recover itself and go on contracting. It is in this restitution process that there is a production of heat; and carbon dioxide is also given off.

It is plain, however, that the ordinary muscle-contractions on a big scale, illustrated when we move about, are not necessary for the warmth of the body, for the sleeping baby is producing heat though it is lying almost perfectly quiet. The blankets, which are comparable to fur and feathers and fat, are not *producing* any heat, they are merely lessening the loss that is bound to occur on the skin and in the out-breathed air.

Muscles continue to produce heat though they are not contracting in the ordinary way. But the broad fact is that the living creature is always undergoing combustion; it is like the burning bush of old, aflame yet not consumed. *Nec tamen consumebatur.* This great fact was made clear by Lavoisier, who was the first to place the purring cat beside the burning candle and to show that they were alike in this, that both were burning away. He invented a ' calorimeter ' for measuring the heat produced by living creatures in different conditions.

Backboneless animals and the lower backboned animals, namely, fishes, amphibians, and reptiles, produce heat, but they have very little capacity for conserving it or for adjusting supply and demand. They are said to be **cold-blooded**; they always approximate to the temperature of their surroundings, and exceptional cases like the congested beehive are readily explained. But ' cold-blooded ' does

not mean that an animal has a low temperature, for this could not be said of lizards basking in the sunshine in warm countries; it means that their body-temperature changes, up or down, according to that of their surroundings. So this is a case where a technical term is needed to correct the misleading popular one, and the word used is **poikilothermal**, which means 'of varied temperature,' in contrast to **stenothermal**, which means 'of practically constant temperature.'

The quality of **warm-bloodedness** is restricted to birds and mammals, and it means the power of keeping the temperature of the body constant, day and night, year in and year out. A bird or a mammal may *feel* cold in winter, but until a certain limit is passed, it has the same temperature as it has in summer. It is stenothermal. The warm-blooded creature can keep its temperature account balanced from hour to hour, almost from minute to minute.

If a bird or a mammal is losing too much heat from its skin and in its breath, the blood is for the moment slightly chilled. When it flows through a particular centre in the brain (situated in the *corpus striatum* of the cerebral region), its slight coldness stimulates the nerve-cells to send out nervous messages which save the situation. Some of these messages command the muscles to produce more heat, while others command a constriction of the superficial blood-vessels in the pale skin, thus reducing the loss.

Similarly, if a bird or a mammal or a man is becoming too warm, the **heat-regulating** or **thermotaxic** centre is affected by the slightly warmed blood, and orders are automatically issued which induce less activity in the muscles, greater activity in the sweat-glands (in mammals), and an expansion of the superficial blood-vessels in the flushed skin. Thus again things right themselves, and without our knowing anything about it. The evaporation of the **sweat** from the mammalian skin helps to keep the body cool; and since birds have no sweat-glands, it is easy to understand why they often 'feel the heat' so badly.

A more or less naked nestling left exposed by some accident to its mother soon takes on the temperature of the surroundings, and thus, in the north,, quickly dies of cold. The same is true of very young mammals that are born naked. In both cases the heat-regulating centres are not as yet in working order. Nature legislates for the normal, and that includes maternal care. Also exceptional are the hibernating mammals, such as duckmole, dormouse, hedgehog, and bat; for these are imperfectly warm-blooded creatures that make a strength out of their weakness by becoming winter-sleepers.

But we must go back to where we began and lay emphasis on the fact that the chief use of the animal heat is to enable the chemical work of the living laboratories of the body to go on quickly and smoothly.

Hormones

One of the many striking discoveries of the twentieth century is the recognition of the regulative rôle of the **ductless glands,** such as the thyroid and the suprarenal. Most of these ductless glands, also called **endocrinal glands,** have been known for a long time; what has been discovered (by Bayliss and Starling) is the use of the **hormones** which they produce. These are transparent chemical messengers which are distributed by the blood, and serve to hasten or slow the activity of susceptible parts. They regulate the complicated chemical routine of the body so that it works smoothly. Our health of body and mind depends on them; and they have made both the everyday and the extra-day life of the body much more intelligible. Not much is known of them except in Vertebrates. Perhaps we shall understand them best in an elementary study if we take a familiar instance of their action in the life of the cat.

HORMONE ACTION IN THE CAT.—When a cat, half-surprised, turns to face a meddlesome dog, it arches up its body and its sleek fur rises on end. The dog is often taken aback by the cat's sudden attitude of resistance, and perhaps by the apparent increase in bulk. More important, perhaps, is the ugly look in the cat's eyes—a look that means business—and the dog often finds it convenient to become profoundly interested in something else.

Several naturalists of half a century ago went the length of saying that the cat deliberately made itself bigger in the eyes of the dog by willing its fur to stand on end, but we now know that what happens is something very different from willing, or taking thought. Whether the cat is really much afraid is a difficult question, the answer to which, perhaps, depends a good deal on the temperament and experience of the individual cat, but it is probably true that in most cases puss is on the border-line of fear, and that in all cases she is considerably excited. Our question now is as to the bodily side of all this.

To answer this question we have to know that inside the cat—as in all other mammals—there is in front of each kidney a small organ called the **suprarenal body,** which is now known to play a very important part both in everyday life and in extraordinary situations. It is a gland making a secretion called **adrenalin**; but it is a ductless gland, and the adrenalin it makes is liberated into the blood, not into a cavity, as is the case with the secretion of a digestive gland, which passes into the food-canal, nor on to a free surface, as is the case with the secretion of the sweat-glands, which is poured out on the skin. The adrenalin manufactured in the central portion of the suprarenal organ is distri-

buted by the blood through the body, and has extraordinary effects in various parts.

It is one of a set of bodies called hormones—or stirrers-up—which travel as ' chemical messengers ' from one part of the body to another, and always promote the welfare of the creature as a whole. Now, an extra production of adrenalin has many effects, such as increasing the pressure of the blood-stream, the vigour of the heart-beat, the tone of the muscles, and so on; and one of the minor effects is to contract the tiny smooth muscles which raise the hairs. We now begin to see the circle of events. Strong emotion, such as fear, means great activity in the central nervous system; it may be a sort of nerve-storm. The news spreads through the body by the nerves, and the suprarenal body is stimulated to an extra production of adrenalin. This powerful hormone is distributed by the blood to parts both near and distant, the tiny muscles which raise the hairs contract, and the cat's fur stands on end. The whole thing takes place very rapidly; it might almost be called automatic if that word did not suggest a machine, which is not a good term to use when speaking of a living body, especially when emotion plays a part.

When we feel very much afraid, part of our fear consists in picturing consequences in our mind and in anticipating pain; and it is not likely that there is very much of this among animals. But we dare not be too sure on the subject, especially when we are dealing with creatures endowed with fine brains, as the cat is. We are on surer ground when we recognize that the bodily side of fear is much the same in ourselves as in the cat. Emotion excites an extra flow of adrenalin, and it is the influence of this hormone that makes our hair stand on end, dilates the pupil of our eye, makes us pale with fright, and so on. One of the many interesting things about adrenalin is that it can now be made artificially in the chemical laboratory. It is sold in the druggist's shop, and used to stop nose-bleeding and the like, for one of its many potent properties is helping the blood to clot.

If we consider the emotion of anger, or rage, the case is even more striking. When a man comes to know of some act of cruelty, or breach of faith, or false accusation, he experiences righteous anger; or he may get into a rage because of some trivial insult, or without any good reason at all. If the man's anger is real, the nervous storm associated with the emotion affects the suprarenal bodies and provokes an extra flow of the adrenalin hormone. This is distributed by the blood, and it almost instantaneously brings the body into an excited state, often very well suited for a fight, or a tussle, or some great exertion. The pressure of the blood-stream is notably increased, and the blood tends to pass from the lower internal regions to the heart, lungs, nervous system, and muscles. The heart beats more vigorously than usual; the amount of

gently and at low temperatures. The production of heat in the animal body we have already studied, and we noted, what every one is familiar with in himself, that while the heat is produced abundantly, the body remains at a low temperature compared with that in a test-tube or a crucible when somewhat similar chemical changes are brought about. It is also plain that strong acids or alkalis would work havoc in the delicate cells of the body. The way out which living creatures somehow discovered, and have made the most of, is to produce ferments, which do astonishing things in a quiet way. This is part of the secret of life, but, unfortunately, we do not as yet fully understand the secret of ferments.

HISTORY.—No one can tell when man discovered that the juice or must of the grape, and the sweet extract or malt that seeps out from soaked grain, gave rise by a strange process of bubbling or boiling to wine and beer respectively. From the Latin *fervere*, to boil, came the word 'ferment'; but man doubtless took advantage of natural or accidental fermentation for long ages before he knew about particular fermenting agencies, such as **yeast.** The process of fermentation was thought of superstitiously, or, with more insight, as somehow akin to life; but gradually men came to know that it was advantageous to keep some of the **leaven** from a good baking to use for bakings to follow, and to use some of the **barm** from one good brew to start another, and to use the same kind of grapes, unmixed with others, to secure the same quality of wine. This is clear to us now, for we know that 'leaven' and 'barm' and the like consist of yeast-plants that change sugar into alcohol and carbon dioxide in all the three instances mentioned. Some of the carbon dioxide is lost from the vat or in the oven, but part is usually retained, giving the beer its briskness, or the loaf its spongy lightness.

There are 'wild' yeast-plants almost everywhere in the atmosphere, so that fermentations of exposed sugary material can take place anywhere, but some kinds of yeast are more effective than others; and thus long before yeast-plants were known as such, it was seen to be advantageous to keep to particular kinds of ferment-causing material, whether that was called 'leaven' or 'barm' or something else. Also of old standing was the custom of boiling wine which was to be exported, or adding some preservative, the object being to prevent further fermentation (e.g. to vinegar) in the course of the voyage.

Yeast-corpuscles were detected about 1780 by Leeuwenhoek, a pioneer microscopist of extraordinary vision, but he did not recognize that they were living. That discovery was made much later, in 1837, by Cagniard de la Tour and by F. Kützing; and even then it was not appreciated. The influence of Liebig and some other great chemists, who were grappling with the chemical facts of brewing and the like,

was so strong that the idea of fermentation being a *vital* process met with determined opposition.

It was reserved for Pasteur to prove up to the hilt that certain fermentations were inextricably bound up with the life of certain micro-organisms, as is alcoholic fermentation with the life of the yeast-plant, and acetic fermentation with the life of the acetic bacterium, and so on. The Pasteur school tended to the exaggeration that the life of the specific microbe was everything in fermentation; the Liebig school tended to the exaggeration that life counted for nothing. On the one hand, cases were adduced where the fermentation failed to occur when means were taken to exclude or kill the fermenting micro-organisms; on the other hand, cases were adduced of striking fermentation without any demonstrable micro-organisms, as happens with bitter almonds crushed with a little water.

Thus there arose a too hard-and-fast distinction between 'organized ferments' known to be living organisms, like yeast and certain bacteria, and 'soluble or unorganized ferments' like the non-living, starch-fermenting 'diastase' prepared from brewers' malt. In 1878, however, Kühne took a momentous unifying step by proposing the term **enzyme** (*en*, in; *zyme*, yeast) for *all* fermenting agencies, whether they were bound up with micro-organisms or not. The yeast-plant does its work of alcoholic fermentation because it produces within itself an enzyme or fermentative agent, but this (as Buchner afterwards showed) can be squeezed out of killed yeast and yet do its usual work. Thus the sharp contrast between living and non-living ferments broke down, the term 'enzyme' passing into general use, to include (1) ferments like pepsin and trypsin, which are not in any essential way associated with micro-organisms, and (2) the ferments produced by yeasts and the like. It must be carefully noted, however, that all enzymes are produced by living cells, that none is known pure, and that their chemical composition is uncertain. Ferment became a popular word, very convenient withal.

CATALYSTS.—No one quite understands ferments, but we cannot understand them at all unless we have first got some hold of the meaning of a larger class of bodies which are called 'catalysts.' All enzymes or ferments act as catalysts, but not all catalysts are ferments. Many catalysts have nothing to do with living creatures, but all enzymes are vitally produced. What, then, is the idea of a catalyst?

Many chemical reactions are almost instantaneous, but others proceed in a leisurely way, like the very slow union of oxygen and hydrogen at ordinary temperatures, or the turning of an ester into a soap under the action of a caustic alkali. These slow-going changes can be greatly quickened by the presence of certain bodies, such as

finely divided platinum in the case of hydrogen and oxygen, water being rapidly formed. *A catalyst is a body that changes the rate of a chemical reaction without itself undergoing any change in weight or chemical composition.* Usually, but not necessarily, the catalyst speeds up the pace; a few are known to slow it down.

It is characteristic of catalysts, such as colloidal platinum (or traces of iron or manganese) when hydrogen peroxide is oxidizing some substance, that they are not involved in the final result of the chemical change, but are found at the end unaffected. Moreover, if there is plenty of time, a little of the catalyst is as good as a large quantity. In some cases it looks as if transitory, intermediate compounds were formed between the catalyst and the substances that are reacting; but in most cases Faraday's theory is probably sufficient, that there is very close condensation and compression of the reacting substances on the surface of the catalyst. In the catalytic combination of hydrogen and oxygen by spongy platinum, the gas molecules are brought into very close quarters on the surface of the metal.

The late Sir William Bayliss, who greatly advanced the understanding of enzymes (see his book, *The Nature of Enzyme Action*, 1925), suggested a mechanical model which is of service in illustrating the kind of thing that catalysts (including ferments) do in altering the rate of chemical reactions.

Bayliss pictured a brass weight at the top of an inclined plane of polished plate-glass. At a certain slope of the plane the weight will slowly slide down; but if the bottom of the weight be oiled (oil= catalyst), the rate of the fall will be greatly increased. In a general way this is what catalysts (including ferments) do; and it will be noticed that the *form* of the energy is altered. For if the unoiled weight slides slowly down, most of the energy appears as heat due to friction against the glass; while in the case of the well-oiled weight, most of the energy is present in kinetic form at the end of the fall. A similar remark might be made in regard to some fermentations.

CHARACTERISTICS OF ENZYMES.—Enzymes (or ferments), such as digestive juices, are 'catalysts produced by living organisms'; and they have the following general properties of catalysts: (1) they do not exactly start reactions; it is rather that they change the rate of what has already begun, usually quickening it; (2) they do not form part of the changed material or 'substrate'; and (3) a little can go a long way.

Enzymes, as distinguished from catalysts in general, are marked by the following characteristics:

(1) They are **colloids** of the emulsoid type; that is to say, innumerable ultra-microscopic particles or droplets of a substance, each containing more or less water of 'imbibition,' are suspended in a watery solution

of the same substance. The device called the **ultra-microscope** shows disks of light refracted from the surfaces of the suspended particles, which are too small to be themselves visible, and shows that they are in a state of vigorous **Brownian movement** (discovered by Robert Brown, the botanist, in 1827). This very interesting movement, easily seen with an ordinary microscope in a drop of water with fine coloured particles suspended in it, is due to the bombardment of the particles by the vibrating molecules of the fluid. The most important feature about the innumerable particles in a colloid is that they necessarily present an enormous total surface, on which chemical and physical changes can take place. Let us think of a drop of colloid as like an archipelago of countless islets, whose coast-lines afford great opportunity for fishing and trading.

This enormous development of the surface on the countless particles of the ferment-emulsion helps us to understand the power that ferments have, for they probably bring the interacting materials into very close quarters on their surfaces. One of the things that happen is called **adsorption,** which is a kind of surface precipitation, well seen (in a simple case) when charcoal is added to a weak solution of a dye like methylene-blue, the result being so great a capture of the dye by the interstitial surface of the charcoal that the fluid passes through clear.

(2) Enzymes are usually very **specific** in their action, which could not be said of an inorganic catalyst like spongy platinum. The metal can quicken various processes, but an enzyme helps on the changes in one kind of substrate (or material) and in one only. It may, however, help to quicken a breaking-down of molecules, and in other conditions a corresponding building-up, for the action of enzymes is characteristically *reversible*. It should also be noted that enzymes are very sensitive to external conditions, such as temperature and acidity; and some show themselves unable to 'leaven the whole lump,' for they are destroyed or in some way smothered by an accumulation of the material they help to produce.

(3) There seems good reason to believe that enzymes are definite chemical substances, but their chemical structure has not been worked out. The negative statement can be made, that they are *not* proteins. Those that have been obtained in purest form are amylase (concerned in changing starch into sugar), invertase (hydrolysing sugar), lipase (attacking fats), pepsin (digesting proteins), and peroxidase (decomposing hydrogen peroxide). Some investigators, like Willstätter, believe that an enzyme consists of (*a*) a colloid-carrier, on which adsorption occurs, and (*b*) a more subtle substance which is the actual catalyst. All enzymes are formed by living matter, and the stage before they acquire their active properties is called 'zymogen.' It usually takes the form of very minute granules. The most recent

refinements of the theory of ferments will be found in J. B. S. Haldane's *Enzymes* (Cambridge University Press, 1930).

IMPORTANT ANIMAL FERMENTS.—It is understood, then, that ferments or enzymes are of vital importance because they quicken the rate of chemical changes, which would go on very slowly of themselves. The ferments have their finger in many a pie, and this is what we now wish to illustrate.

(1) **Ferments concerned in Digestion.** As we have mentioned, digestion means dissolving the food and also making it more readily diffusible by breaking down large molecules into smaller ones, which pass more readily through the lining membranes of the intestine into the blood-vessels and the lymph-vessels. Most digestive ferments help in a process of *hydrolysis* (p. 918), which means that water is added to the material or substrate, and a splitting-up follows. To the molecules of the food (in the case of digestion) molecules of water are added, and then the combined molecules split into two. The cleavage products may be equal or unequal in molecular size, and one or both of them may be combined again with more water, the splitting process being then repeated. The result of this may be that protein molecules are broken down into smaller amino-acid molecules, so completing the digestion. Similarly, starch molecules may be broken down into sugar (glucose), or fat molecules into fatty acids and glycerine. Among the hydrolytic digestive ferments we may mention amylase or ptyalin from the salivary glands, changing starch into maltose; amylase or amylopsin from the pancreas or sweetbread, doing the same; invertase, changing sucrose (cane-sugar) into two other sugars—glucose and fructose; lipase from the pancreas, changing fats into fatty acids and glycerine, which pass into the lymph-vessels; pepsin from the stomach glands, changing proteins into peptones and the like; trypsin from the pancreas, changing proteins into amino-acids and similar substances; erepsin, changing peptones into amino-acids.

In very simple animals, like zoöphytes and some worms, the *solid* particles of food are in part engulfed by the cells lining the food-canal, and then digested within them by *intra*cellular ferments; in all other cases the digestive ferments are liberated into the cavity of the gut and do their work there, the dissolved and simplified products being subsequently absorbed.

(2) **Coagulating Ferments.** A few enzymes are concerned in binding together, rather than in splitting up. They are factors in coagulation, and may be illustrated by the curdling ferment called **rennase**, from the calf's stomach or from the pancreas, which has to do with changing the caseinogen of milk into casein. This rennase is regarded by some as the same as pepsin.

We have all watched the **clotting of the blood** that has flowed from a

wound in our hand. In this very interesting and intricate process part of the fluid of the blood sets in a jelly, traversed and bound together by crystalline threads of **fibrin** Some investigators rank among enzymes a substance called **thrombin,** which has to do with forming the fixed fibrin out of a soluble protein, fibrinogen.

(3) **Ferments that promote Oxidation.** Widely distributed in animal tissues are enzymes that assist in oxidizing or burning away various substances. They are called **oxidases.** Somewhat similar are the peroxidases that act on peroxides; and one of the most important of enzymes is the **catalase** of the green leaf that helps in the production of oxygen and water from hydrogen peroxide.

A widely distributed animal ferment is **tyrosinase,** which promotes the oxidation of the amino-acid tyrosin. On the opposite side, but few in number, and hardly requiring a separate group in this simple survey, are the **reducases** that help in deoxidation or reduction.

(4) **De-aminases.** This is a very unfamiliar word, but it is the name of a very important group of animal ferments whose general rôle is not difficult to understand. All ordinary animals require protein food; this is broken down (with the help of digestive ferments) into amino-acids; these are used in part to replace the broken-down protein building-stones of the living matter, or to add to them if there is growth; but there is usually a surplus of amino-acids, and these are dealt with in the liver. The nitrogen in an amino-acid is in the form of an amino-group (NH_2), and this is split off (de-aminated) in the liver to form ammonia, which in turn (being a cell-poison) is rapidly combined with carbon dioxide and water to form ammonium carbonate. By removal of water, probably in the liver-cells, this is changed into **urea** (p. 943), which is got rid of in the urine.

To complete our outline of a fascinating story, we may notice in passing that the nitrogen-free residues of the de-aminated amino-acids, which have a carbohydrate or a fatty character, are oxidized to yield energy to the body. Our particular point, however, is that certain ferments assist in the fundamentally important process of de-aminating; and these are called 'de-aminases.' When standing urine begins to give off ammonia and carbon dioxide, another ferment, called **urease,** is assisting in the breaking-down of urea. And so we must conclude our sampling of the ferments which play so important a part in so many corners of animal life. We have said enough to show that life would be a slow business without ferments.

Size and its Limits

RANGE OF SIZE.—Thousands of bacteria may lie within the smallest letter 'o' on this page, and a tiny insect with legs, muscles, food-canal,

and nervous system may rest, as we are reading, inside the largest. On the other hand, a big tree (*Sequoia gigantea*) may grow as high as the railway line of the Forth Bridge is above low tide; and the jelly-fish *Cyanea* may be $7\frac{1}{2}$ feet across its circular disk and have tentacles 120 feet long, swaying in the tide.

In their very educative *Animal Biology* (1927) Haldane and Huxley note, in regard to the range of size in organisms, that 'a Big Tree may be as many times larger than a small Bacterium as the sun is larger than the Big Tree.' 'The largest elephant has clearance top and bottom inside a whale.' This great range of size raises interesting biological problems, and the authors to whom we have referred give a very interesting table of comparative dimensions from the smallest free-living protozoön to a whale. We cannot do more than raise the question of this extraordinary range of size.

LIMIT OF GROWTH.—In a few cases a single cell swells (*a*) by the accumulation of water, as in a giant multinucleate alga called *Botrydium*, or (*b*) by the accumulation of nutritive material, as in many a yolk-laden ovum. We suppose the largest cell in the world must be the centre of the unfertilized ovum of the ostrich, where a small drop of protoplasm with a central nucleus lies on the top of an enormous mass of non-living yolk. To begin with, the bloated cell has a delicate film-like **vitelline membrane**, but as yolk is accumulated this is replaced by a firm multicellular capsule, which prevents bursting.

But while there are a few large cells like the above, the majority of cells are very small; thus the human body starts from a cell $\frac{1}{125}$ of an inch in diameter when it is still in the maternal ovum. What must be the minuteness of the cells in some of the puzzling dwarf insects and crustaceans, which have many organs and yet are not larger than the egg-cell just referred to!

One reason why most cells remain small is that they soon reach a limit of growth due to the disproportion that sets in between increase of volume and increase of surface. Another reason may be found in the fact that a nucleus seems unable to control the life of more than a small amount of cytoplasm.

Reasons analogous to those which bring about a limit of growth in most cells may account for the fact that most animals have a definite **limit of growth.** This is probably the size in which the animal is physiologically most stable, when the amount of surface—internal as well as external—is just that which serves to meet the needs of the amount of living matter that has to be kept alive. Different species of house-fly have different sizes, but all the individuals of the common *Musca domestica* are usually of the same size. In the majority of familiar animals, such as birds, the members of each species have approximately the same size when full-grown in suitable surroundings.

Of course there are exceptions; thus many fishes show no definite limit of growth, but go on increasing until they come to a violent end. We have seen a haddock as large as a cod. The same persistent increase of size is illustrated in many reptiles, such as crocodiles. But the broad fact is that in the majority of animals there is a definite limit of growth; *there is a size which is physiologically fittest.*

LARGE AND SMALL.—But while we find physiological reasons for the limit of growth, we have still to face the question: Why do some kinds of organisms grow large, while others remain small? Perhaps the beginning of an answer may be found in the fact that one of the deepest—if not the deepest—of differences between one animal and another is in the ratio between upbuilding (anabolic) and down-breaking (katabolic) processes. Thus plants have an $\frac{A}{K}$ ratio in which the numerator is always relatively large, plants living far below their income. It may be that the deep difference between a male and a female animal is in this $\frac{A}{K}$ ratio, for anabolism is sometimes *relatively* predominant in the female and katabolism relatively predominant in the male. A variation or new departure often means an increase in the numerator or in the denominator of the $\frac{A}{K}$ ratio. It has been proved that a crustacean species at home in the swift river may differ in its rate of metabolism from a closely similar species living in quiet ponds.

It may be, then, that the organisms that remain small are those with a protoplasmic constitution in which anabolism is from the first relatively less than in related forms which grow large. The extremely anabolic types tend to become the giants, and the extremely katabolic types run the risk of being dwarfs. Contrast a super-active aërial may-fly with one of the largely appetized giant cockroaches.

Relatively slight anabolism retards the rate of cell-division, and this may keep down the size. It may also reduce the total number of divisions that a particular type of cell can exhibit. Thus nerve-cells in Vertebrates multiply quickly in the embryo and well-nourished young, but soon come to an end of their capacity for adding to their number. In mammals, for instance, the cells in the brain, though often very numerous and contributing to a large organ, do not multiply (i.e. divide) after birth. Our suggestion is that a restriction of cell-division in the less anabolic types may be a factor in keeping an animal small.

Another point is that size is in part regulated during development by the hormones secreted by endocrinal glands, such as the pituitary body. Thus variations in the activity of this body may bring about abnormal giants and dwarfs in mankind, probably to be firmly

distinguished from those giants and dwarfs who are not only wholesome, but often very able.

But while we start with the theory that size depends primarily on the constitutional or inborn ratio of anabolism (construction) and katabolism (disruption), we must add the idea that size is often related to the conditions of life. In one word, it may be adaptive. Thus the whales, the giant animals of to-day, have their colossal body supported by the water; the huge python has its great length and weight supported on the ground or on the branch; the jellyfish that may weigh a ton is a floating giant. There may also be some relation to the habitual food-supply, whether abundant or sparse; to the temperature (for cold lessens the rate of cell-division); to the foothold in the struggle for existence, and so on. Minute animals are often well adapted to life in crevices, to escaping detection, to withstand external vicissitudes, and so forth. In short, the size of animals, and in some measure of plants, is often **adaptive.**

Animal Pigments

WHAT COLOUR MEANS.—We live in a world rich in colour—of sea and sky, of mountains and precious stones, and, finest of all, of plants and animals. The colours are our sensations, due to what particular wave-lengths of light reach our retina, and thence excite our brain. When all the ordinary light-rays of different wave-lengths reach our eye, we see the common light of day or, it may be, a white object; but if only a *fraction* of the ordinary light reaches us, we see some colour or other according to the fraction. At the one end of the spectrum, familiar in the rainbow, there are the violet rays with shortest wave-length, some forty millionths of a centimetre long; at the other end are the red rays with longest wave-length, twice as long as the violet. According to the wave-length is the colour-sensation; and it is worth remembering that ants, as Sir John Lubbock first showed, can see the ultra-violet rays which are invisible to us, though happily we are not insensitive to their healthful influence. If we call visible light an octave, there are sixty-one other measured octaves of electro-magnetic vibrations, from the very short-waved rays used in radio-therapy to the very long ones used in broadcasting; and while different notes, so to speak, of the visible light-octave call forth different colour-sensations, a blend of all the notes, as from snow, foam, clouds, and the like, produces the sensation of *whiteness*, for there is complete reflection of the whole light from the mirroring surfaces of crystals or bubbles as the case may be. When the light comes to our eye after passing through a coloured body or fluid, or after being reflected from a coloured surface, then it has been to some extent filtered or

tampered with. Whenever that is the case, we see *colour*, which varies according to the nature of the filtering. Thus if the rays of longest wave-length (red) have been absorbed or in any way subtracted, then the object will appear green—the colour 'complementary' to that which was filtered out. If 'blue' is filtered out, the object will appear 'orange.' We must not dwell on this physical aspect; the point is that 'colour' is due to some interference with the wholeness of white light.

THREE KINDS OF COLORATION.—Among plants and animals there are many substances, called **pigments**, the molecular structure of which is such that they interfere with the wholeness of the light that passes through them or is reflected from them. In a rough way, they might be compared with paints, but this is a case where a simple comparison is not a very useful one, especially when we come to face certain peculiar 'pigments' which have little or no colour! That a pigment may be colourless is a statement to disbelieve until one understands it.

As examples of organic pigments we may mention the two most important, **chlorophyll** in plants and **haemoglobin** in animals, which are very different from one another, though with a good deal in common. The chlorophyll pigments, for they are in the plural, absorb some of the orange-yellow-red rays, and use this energy to built up carbon dioxide and water into sugar and the like—the most fundamental vital process in the world. The red blood pigment or haemoglobin of all higher animals owes its great importance to its power of capturing oxygen, e.g. in the lining of the lungs, and of readily surrendering it again to the living matter of the body. The **melanins** of dark-coloured birds and beasts, e.g. crow and black Angus, are familiar examples of pigments; and every one knows, though not by name, the reddish pigment (**zoönerythrin**) of shrimps and prawns, which is bluish in the lobster until it is boiled. First of all, then, the colour of an animal may be due to particular organic substances or pigments, whose structure is such that it somehow interferes with the wholeness of the white light that falls upon it.

In the second place, there may be brilliant colours without any pigment at all, as is plain enough from the iridescent soap-bubble. The bubble has all the colours of the rainbow, but it is only a transparent film of soap and water. Every one knows the beautiful colours of mother-of-pearl; but if the shell is pounded, it is only white chalk. The colouring in this and other cases is due to the way in which the light is reflected, from a film in the soap-bubble, from a finely layered or laminated texture in the pearl-oyster's shell, or from a delicate surface graining or cross-hatching in many other cases.

In the third place, the colouring of the animal may be due to a combination of pigmentary and structural (or physical) coloration; and this gives the finest display of all. We are familiar with it in the peacock's tail-feathers (really the 'tail-coverts') and in many brilliant butterflies. There is an underlying pigment, the effect of which on the light that falls on the body is enhanced by the fine structure of the surface. In many cases the pigment is a simple brown, but the external sculpturing makes it like a living jewel. Often there may result a bright colour, such as blue, which is not hinted at in the pigment. A bruising of the texture spoils the fineness of the colouring, and another feature is that the colour changes a little as the animal moves, or as we move, for different parts of the rainbow colouring reach our eye. This is familiar in many birds with so-called 'metallic' glimmer in their plumage. To sum up, coloration may be (1) *pigmentary*, as in the ruddy animal or the green plant; (2) *structural*, as in mother-of-pearl; and (3) *a combination of the two*, as in peacocks' feathers.

BLOOD PIGMENTS.—For several reasons we give the first place to the blood pigments, such as the haemoglobin of all the higher animals. The increase of vigour as we ascend the scale of life is partly due to the abundance of haemoglobin and the use that is made of it, because, as we have said, it has the power of readily entering into a loose union with oxygen, captured in various ways, e.g. on the internal surface of lungs, or on the external surface of gills. Man has some twenty-five thousand millions of red blood corpuscles, which, if spread out, would cover a surface of over three thousand square yards! Thus, taken together, the red blood corpuscles represent a very extensive internal surface for oxygen-capture. The mere possession of haemoglobin however, does not mean a high status in the scale of being, for the earthworm's haemoglobin is much the same as ours. As far as we know, the first animals to produce or, so to speak, invent haemoglobin were certain marine worms, known as ribbon-worms or Nemertines; and this was one of the momentous steps in Organic Evolution. It opened the portal to higher life. Yet it must be noticed that among backboneless animals there are some other blood pigments, similar to haemoglobin, but not so effective. Thus **haemocyanin** is common among crustaceans and molluscs.

Haemoglobin has a very complex chemical composition, with a large molecule. It may be split into two parts: (1) colourless protein called **globin**, which varies greatly from one type to another, and (2) a constant coloured portion called **haematin.** This consists of four pyrrol rings linked together by an atom of iron—a pyrrol ring being $\begin{matrix} \mathrm{C{=}C} \\ | \\ \mathrm{C{=}C} \end{matrix} > \mathrm{N}$,

four atoms of carbon united with one of nitrogen.[1] There is a remarkable reason for mentioning this point, even in an elementary article, for the same pyrrol ring occurs in chlorophyll, the characteristic green pigment of plants.

There is a continual breaking-down of haemoglobin in the body, and some of the products almost certainly give rise to pigments of the bile in backboned animals, such as the green **biliverdin.** Other disintegration products of haemoglobin or some related blood pigment are deposited in the tissues of various backboneless animals, such as leeches and molluscs. It may be mentioned that the faintly bluish blood pigment, called haemocyanin, that is common in crustaceans and molluscs, has copper where haemoglobin has iron.

Also related, because containing haematin, are certain pigments called **cytochromes** (cell pigments), that were discovered by Keilin in 1925, and are very widely distributed in plants as well as in animals. They seem to be concerned, not with carrying oxygen over a distance, as haemoglobin does, but with its control at close quarters—within the cell. They occur from yeasts to flowering plants, from Insects to Vertebrates—almost universally.

CHLOROPHYLL PIGMENTS.—Probably much older than the haemoglobins are the chlorophylls of green plants, for on them the process of photosynthesis depends—the building-up of sugars and the like from carbon dioxide and soil-water. Something of this sort must have been achieved before there were very successful animals, for all ordinary animals require for their food the proteins, carbohydrates, and fats that have been formed by green plants or by other animals. In saying that successful animals must have been preceded by green plants, we are not forgetting that there are a few simple animals, such as the green bell animalcule (*Vorticella viridis*), that have chlorophyll of their own. These are not to be confused with various green worms, green sea-anemones, green freshwater sponges, and many green *Protozoa* (unicellular animals), which owe their colour to partner unicellular plants (*Algae*) possessed of chlorophyll. We suggest as a scientific exercise the searching out of at least six quite different ways in which an animal or part of an animal may have a green colour.

The chlorophyll of plants is much more complicated than used to be supposed; it is, indeed, a system of four pigments. Two of these, chlorophyll-α and chlorophyll-β, are essential, for they absorb red and orange rays, thus appearing green; and in the sunlight there seems to be a continual cycle of changes, chlorophyll-α changing into chlorophyll-β, with absorption of carbon dioxide, and chlorophyll-β changing into

[1] Pyrrol itself is $\begin{array}{l} CH{=}CH \\ | \qquad\quad > NH \\ CH{=}CH \end{array}$

chlorophyll-*a*, with liberation of oxygen for which we cannot be too thankful, for this is the origin of our breathable air. The cycle between the two chlorophylls is of great interest, because in the blood of Vertebrates the red pigment shows the same general alternation—between haemoglobin and oxyhaemoglobin. Along with the two essential chlorophylls there are two yellowish pigments, **carotin** and **xanthophyll,** which seem to be much less important and belong to a different group.

Chlorophyll proper, whether α or β, has a large molecule, which is readily split, by the action of an alkali, into two parts. One of these is a complex colourless alcohol called **phytol.** The other has for its foundation four pyrrol rings (p. 938). The four rings are linked together in the molecule, and associated with them in some way is a single atom of magnesium, so like the atom of iron in haemoglobin. The resemblance of chlorophyll to haemoglobin is very striking, and it may be that the former was a stage in the evolution of the latter. But the coloured part of chlorophyll is linked to an alcohol; that of haemoglobin is linked to a protein.

MELANIN PIGMENTS.—This third group includes dark pigments, as in the negro's skin, the polled Angus pelage, the crow's plumage, the choroid lining of the eye, the ink-bag of sepia and other cuttlefishes. There seem to be several different kinds, but melanins are difficult to purify, since they do not crystallize, and since they are very difficult to dissolve. They always occur in the form of minute granules. They may be on the surface, as in darkish birds and mammals; but most people must have noticed the densely black pigment on the lining of the body-cavity of many fishes and other animals.

As to the nature of melanins, there is strong evidence that they are derived from a substance called 'dopa' for short (dihydroxyphenylalanine), which in turn is derived from **tyrosine.** Now tyrosine is one of the amino-acids, which have been called the building-stones of living matter. All living matter consists in essential parts of proteins, and proteins are chains of amino-acids, the links of the chain breaking apart in some bodily changes, such as digestion, and being pieced together in others, as when the protein framework of a cell is repaired after wear and tear.

If pure tyrosine is treated with an enzyme or ferment called **tyrosinase,** which is of wide occurrence in living creatures, it becomes, on exposure to air, first reddish and finally black; and this black pigment seems identical with naturally formed melanin. This is very interesting because the ferment tyrosinase is common and the amino-acid tyrosine is common, so that we can understand that darkish pigments should be common.

FATTY PIGMENTS.—The fourth group of pigments consists of 'coloured fat-like bodies' (*chromolipoids*) or 'fatty pigments' (*lipo-*

chromes), the technical terms being preferable since the substances in question show no great resemblance to fats, save in their solubility in ether. They are widely distributed in plants and animals, and they are often of a yellow-orange-red colour. Two of them have already been mentioned, the 'chlorophyll-yellows,' carotin and xanthophyll, which occur in green plants along with the 'chlorophyll-greens.' Carotin is familiar in carrots, and it gives a yellowish colour to butter. The xanthophyll of many yellow flowers crops up again in the yolk of the bird's egg. The yellow fat of many animals, such as lizards, owes its colour to a lipochrome. Another good example is the reddish zoönerythrin (*zoön*, animal; *erythros*, red), common in many of the crustaceans, such as shrimps, prawns, the Norway lobster, and the rock-lobster (*Palinurus*). Zoönerythrin is a widespread and cheerful pigment, occurring, for instance, in the red wattle above the eye of the grouse; and it is chemically next door to the carotin of carrots. The bluish colour of a living specimen of the common lobster (*Homarus*) is due to this same zoönerythrin, but in combination with a protein. When the protein is destroyed by heating, the free pigment takes on its familiar red colour, so conspicuous on the lobster exposed in the fish-monger's window.

OTHER ANIMAL PIGMENTS.—So far, then, and it is no small gain, we see that the pigments of animals may be ranked in four groups: (1) the blood pigments, e.g. haemoglobin; (2) the small group of chlorophyll pigments, which are mostly restricted to plants; (3) the large group of melanins; and (4) the large group of lipochromes.

It would, however, be giving a false simplicity to the facts if we did not notice that there are many other animal pigments that cannot be referred to any of these clearly defined groups. Thus the wings of some yellow butterflies show pigments related to uric acid, and therefore to be regarded as of the nature of waste-products. The pigment of the marbled-white butterfly (*Melanargia galatea*) is chemically known as a **flavone,** or 'flavonol,' and Dr. David Landsborough Thomson has traced it back to timothy or to cocksfoot grass, on which the caterpillar feeds. Then there is the Tyrian-purple secretion of the dog-whelk (*Purpura*) and some other sea-snails. It is the animal counterpart of indigo, just as the red pigment of the female cochineal insect is a distant counterpart of the alizarin of madder. The cochineal red is perhaps a reserve product; it is chemically a glucoside, yielding sugar when treated with dilute acid. But in an introductory survey it is probably enough to emphasize the four groups: the **blood pigments,** the **chlorophylls,** the **melanins,** and the **lipochromes.**

USES OF PIGMENTS.—We must not embark on the large question of the uses of coloration—a fascinating question deserving treatment

by itself. It is well known that some colours conceal their possessors very effectively, while others advertise their presence; some may attract or excite desired mates, while others may warn off intrusive enemies, and so forth—but let us leave this for future exploration.

The utility of a pigment is a different question from that of coloration, as is evident enough when we think of the cytochromes, which have practically no colour at all. Similarly, most people would say that a lobster's blood is colourless, though it has abundant haemocyanin. A pigment may be of great physiological use though it has little or nothing in the way of colour; and a pigment, like the green of the bile, may be brightly coloured, although we cannot say that its colour, as colour, is of any use.

As to physiological uses, the first place must be given to the chlorophylls, which make photosynthesis possible. Then come the blood pigments, such as the haemoglobins and the cytochromes, which have to do with the distribution of oxygen in the body. It may be that some of the superficial melanins keep the glare of the sun from penetrating deeply into the body; and the absence of any pigment, as in the warm-blooded, snow-white ermine and ptarmigan, may lessen in winter the loss of the precious animal heat. In a few cases, a pigment may be a useful reserve. These must serve as illustrations; and we would close with the caution that while some animal pigments are of vital importance, others are waste-products or by-products, necessary in the normal chemical routine or metabolism of the living body, but of no positive utility—unless we include that of pleasing man with their beauty.

WASTE-PRODUCTS

In an engine like a locomotive or an automobile there are two kinds of waste. There is the unused or incompletely used fuel, whether it be coal or oil; and there is, much less obviously, the fine wear and tear of moving parts. In spite of oiling there is friction, there is a rubbing away of microscopic particles of steel. So in the living body there is part of the digested food that is not fully utilized, and there are wear-and-tear waste-products of the active cells. Let us distinguish, then, these two kinds of **waste-products** in the body.

With many animals, and with man himself, it often happens that a large part of the food is not digested or very slightly digested during its passage through the food-canal. It is got rid of as **excrement** or **faeces,** like the horse-dung on the roads or the rabbit's droppings on the links. This getting rid of the ballast or coarse undigested remains of the food is not to be mixed up with the filtering-out of internal waste-products from the blood or other body-fluids, for this is a much more intricate process. To this only the word **excretion** should be restricted.

It is a familiar fact that when a candle burns, the carbon-compounds are burned away, giving off energy as heat and light, and forming as waste-products the familiar carbon dioxide and water. These are also formed in the living cell and pass into the blood to be removed. The carbon dioxide is got rid of in higher animals on the internal surface of the lungs, and the water is got rid of at the same place, and by the kidneys and skin as well. Carbon dioxide and water could not be utilized or oxidized any further, and we may think of them by themselves as the inevitable end-products of the vital combustion.

The other important waste-products are compounds of nitrogen. These arise (*a*) from the breaking-down of the proteins that form part of the physical basis of life, or (*b*) from the incomplete utilization of digested nitrogenous food. Thus ammonia is formed in both these ways: (*a*) as part of the 'ashes' of the living cell, and (*b*) from the splitting-up of protein-food into amino-acids and other components in the course of digestion. But ammonia is a dangerous and, so to speak, impossible waste-product in a living body, therefore it must be rapidly changed into something less hurtful, such as urea. This is one of the many tasks of that hard-worked organ, the liver. Here the nitrogenous waste is prepared for being filtered out by the kidneys.

UREA.—This is the commonest nitrogenous waste-product in mammals. Along with water and salts it forms the urine. Its chemical composition is $(NH_2)_2CO$, and it was a great step in the history of both biology and chemistry when Wöhler in 1828 manufactured urea artificially; for previous to this discovery the belief was that organic compounds made by organisms could not be made in any other way. For many years now the chemists have been busy with artificial synthesis, and are able to build up not merely simple things like urea, alcohol, and sugar, but much more complicated things like indigo, salicylic acid, caffein, and adrenalin. Among birds the nitrogenous waste consists largely of urates or salts of uric acid; in reptiles and many lower animals the form taken is uric acid. But whatever be the form that the nitrogenous waste takes, the important fact is that it gets filtered out without doing harm. In some cases, but more in plants than in animals, part of the nitrogenous waste is retained within the body in the form of spicules or of **pigments** (q.v.), which may be of great utility. Some plants have the noteworthy power of utilizing their own nitrogenous waste as part of their nutritive supply.

Animal Sleep

Although we spend a large fraction of our life in sleep, we are far from understanding what it precisely means, either for ourselves or

for animals. Sleep is part of an established rhythm, a state of partial fatigue in the higher nerve-centres, during which recuperation occurs, probably associated with the removal of subtle waste-products or **toxins.** It is ‘ natural,’ we say, that rest should alternate with activity. Yet, as we repeat this, the difficulty arises in our mind that many animals—most animals, indeed—do not sleep at all; that many parts of our body, such as heart and lungs, food-canal and kidneys, go on doing their work while we sleep; that our spinal cord must be a very light sleeper, and that the ‘ breathing centre ’ in our medulla does not seem to need a rest all the days of our life. The necessity for rest after work does not carry us far towards an understanding of sleep.

Perhaps there is a flash of light on the problem in the fact that, with few exceptions, only the higher animals seem to require sleep. We must exclude mere resting, seen in many fishes and reptiles; we must exclude hibernation, cold coma, and animal hypnosis; we must exclude the suspended animation of many of the simple creatures that lie low. Sleep is different from all these; it is a peculiar state in which all the everyday functions are continuing; even the muscle-engines are going, though not in gear; the blinds of the body, notably the eyelids, are drawn down; only to a slight extent are we able to ‘ answer the door ’ to the knockings of the outer world; except in somnambulism, we have very little power of moving about without first awakening. In this sense a number of the more intelligent mammals, like horse and dog, are genuine sleepers. A dog that cannot get a sleep will die in four or five days. On the other hand, it is said that some of the less intelligent mammals, such as guinea-pigs, never fall asleep. This points to the theory, suggested by Professor Hempelmann, that sleep is a tax on having a really fine fore-brain. The less intellectual the animal, the less sleep it needs. We pay for our wits by becoming sleepy.

This theory may be restated in more physiological language. It may be that sleep is an **auto-intoxication** with a specific fatigue-toxin produced by the higher centres in the cerebral hemispheres. No doubt there are exceptional cases which test the rule somewhat severely. Thus, hens are said to sleep, and the basking shark may be caught napping. Moreover, some very clever men need little sleep, whereas, according to the theory, they should require more than the average. Still, it is worth thinking over the hypothesis that the need for sleep is a tax that the active mind makes the body pay. And it is of some interest that sleeping apes, dogs, cats, horses, and the like, utter sounds and make movements the like of which, in man's case, would be regarded as indicative of **dreaming**—a more or less unregulated activity of alert minds when the bulk of the body is asleep.

CHAPTER VI

GLIMPSES OF ANIMAL BEHAVIOUR

Tropisms—A nerve-thrill—Instinctive behaviour—Triumphs and limitations of instinct—Intelligence of a wasp—Animals at school—Intelligence of chimpanzees—Play in animals—The feelings of animals—Personality among animals.

THERE are two main trends of behaviour: on the one hand, responses such as reflexes, tropisms, ingrained rhythms, instinctive actions, that are the outcome of an inborn or acquired repertory; on the other hand, tentative experiments, initiatives, pre-intelligent efforts, associative learning, intelligent and, in man, rational actions.

TROPISMS.—We have given numerous examples of tropisms. These are **obligatory movements** which adjust the body so that its two sides receive an equal stimulus. Thus when a moth flying close to a candle has one eye more illumined than the other, it automatically turns so that both eyes are affected alike, either equally illumined, which may mean death unless a reaction to heat occurs in time to save the insect, or else equally unillumined, which means at least a temporary escape from the flame.

A single **reflex action** is a brief and relatively uncomplicated process, and may be regarded as being on a slightly lower level than a tropism; but reflexes may be linked in a chain and then they constitute the physiological side of certain examples of **instinctive behaviour.** It seems impossible to make hard-and-fast divisions, even when we pass from purely physiological responses to activities which involve psychological description, e.g. **intelligent behaviour.**

A NERVE-THRILL.—How quickly a horse answers to a flick; how quickly we draw back our hand from a hot cinder; how quickly an earthworm jerks itself into its hole when the earth vibrates under the light tread of an approaching thrush's foot! These are reflex actions, which do not require to be willed or thought about. They are *automatic responses to stimuli*, and many of them are established at birth, as in the case of sucking in mammals, or when the nestling opens its bill at the touch of the food which the mother brings. Automatic as they are nowadays, we need not be dogmatic in answering the question whether the animal never knew at all what it was doing when these reflexes were established in the course of racial evolution. We do not learn to sneeze, it is reflex; but it does not follow that the withdrawal

of a limb from something hot or sharp was not once—in distant ancestors—to some extent deliberate. Among trained animals and in ourselves we know of skilful movements which required for a long time much attention and control, yet have now become quite automatic. We do not need to think or will in adjusting our push-bicycle even to a difficult situation. Reflexes may be inborn and perfect from the first, as in the young redshank's squatting and remaining motionless when it hears the parent's danger-signal, but they may also be established in the individual lifetime, as in a horse's immediate response to certain touches. Habituation depends on the individual establishment and facilitation of reflexes. Practice makes perfect, as we say.

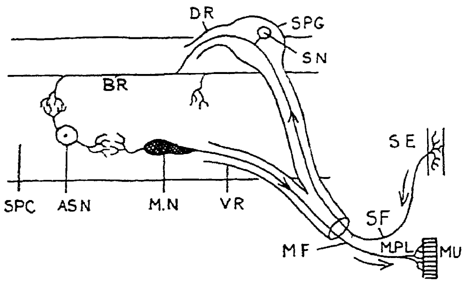

FIG. 308. DIAGRAM OF THE ELEMENTS INVOLVED IN A REFLEX ACTION

SP.C, the spinal cord; AS.N, an associative neurone; MN, a motor neurone; VR, ventral root of spinal nerve; MF, motor nerve-fibre ending in a motor plate (M.PL) on a muscle (MU); SE, ending of a sensory nerve-fibre, e.g. on the skin; SF, sensory nerve-fibre; SP.G, spinal ganglion on a dorsal root (DR) of a spinal nerve; SN, sensory neurone in the spinal ganglion; BR, branches of a sensory nerve-fibre within the spinal cord. The arrows indicate the direction of the message or command. Branches of a sensory fibre come into close contact with branches of an associative neurone; and similarly there is close contact or synapsis between other branches of the associative cell and those of a motor neurone.

But whatever be the nature of the reflex, it always implies (*a*) a message passing inwards along a sensory nerve to something in the way of a centre, often in the spinal cord, and (*b*) a message passing outwards along a motor nerve to a muscle or, it may be, a gland. News pass from the outer world or from some internal organ to something in the way of a **nerve-centre,** and commands pass out provoking a muscle to contract or a gland to secrete. In all typical cases, as we said before, there is a chain of four links: (1) the sensory nerve-cells, which receive the tidings; (2) the associative nerve-cells, which shunt the impulse; (3) the motor nerve-cells, which pass it on to the (4) effecters or muscle-cells. This is so fundamental that we should be humble enough to think more than once of sensory nerve-cells as comparable to scouts, of associative nerve-cells as general headquarters, of motor nerve-cells as executive officers of varied rank, and of effecters or muscle-cells as the ' men ' who do the work.

All this reflex-arc business takes place with great rapidity; thus the

average rate of transmission of a nerve-impulse in man is four hundred feet per second, though in many of the humbler creatures it is much slower. But what is it that travels? This remains one of the most difficult of physiological questions, but some progress is being made. Thus we know that a chemical process occurs, for carbon dioxide is produced and a very minute quantity of heat. There is also an electric current implicated in at least the beginning of the nerve-impulse. If in a long stretch of nerve a part be anaesthetized in some way, this naturally enough delays the passage of the nervous impulse; but if the impulse gets through to the uninjured part, it is as strong and rapid as ever. Thus a nerve-thrill is one of the 'all-or-nothing' phenomena. One wishes one understood it better.

INSTINCTIVE BEHAVIOUR.—Instinctive behaviour is the expression of hereditarily pre-established linkages between certain groups of nerve-cells and certain groups of muscle-cells, and it seems to be associated with some degree of awareness and a backing of endeavour. It is well illustrated by the kitten's reaction to mice. The killing instinct appears suddenly, usually during the second month. In a moment the playful kitten is transformed into a beast of prey. It bristles up its hair; it switches its tail; it may hiss, spit, or growl; it unsheathes and sheathes its claws; it catches the mouse by the back of the neck. The movement of the mouse seems suddenly to liberate an inborn capacity, a ready-made trick; but the odour of the mouse also counts, and counts increasingly. If the kitten grows up inexperienced as regards mice, the instinct seems to become more and more difficult to evoke; but the young kitten can kill in the fit and proper way without either experience or imitation. At first the killing tends to be immediate; 'playing with the mouse' comes later. Our point is that Natural History has got far beyond mixing up instinctive behaviour with intelligent behaviour, or even with tropisms or forced movements.

TRIUMPHS AND LIMITATIONS OF INSTINCT.—As one goes about the country in summer, when life is at full tide, one sees many instances of triumphant instinct, sometimes perfected, we think, with a gleam of intelligence. At other times one sees the efficiency of instinctive behaviour defeating itself by its tyrannous routine, as when an Indian file of procession-caterpillars (q.v.), bent round to make a circle, continues in futile circumambulation for hours and hours. Oftenest, however, it is the successful efficiency that we have to admire. Thus we came across a horizontal web which a spider had constructed over a sluggish ditch banked by willow-herbs. The ditch was broader than we could jump, and the bridge was suspended about a yard above the water. It was more than a bridge, of course; it was the usual insect-snaring web, a swaying sheet approachable from either bank.

So far as we understand, it is impossible to account for the making of such a bridge-web, in a situation which could not be walked round, except on the assumption that the spider took advantage of currents of air which wafted across the first strand or strands. From one side she paid out a thread of silk which she fastened where she stood, facing the direction from which the breeze blew. When the silken thread was long enough, its free end became entangled among the herbage on the far side. In all likelihood a second thread was made parallel to the first. Then the spider crept cautiously across the swaying line, paying out more silk and strengthening the first threads as it went, and then pulling taut on the further bank. After that, all was easy—for a spider. The result was certainly an achievement commanding our admiration, and we have no doubt that we could see a bridge in process of being made if we went often enough to a suitable place where spiders abound. If the achievement stood alone, it would be almost necessary to regard it as an expression of high intelligence, but it is led on to by a gradation of minor accomplishments which we know to be instinctive, that is to say, the outcome of inborn hereditary capacities for going through an effective routine, requiring no apprenticeship. Thus a young garden-spider can make a web true to type the very first time it tries. There is no prentice hand, for though a stronger web is afterwards made, there is no fumbling with the first, and the pattern is that characteristic of the species.

In his admirable *Problems of Instinct and Intelligence* Major R. W. G. Hingston tells us of a spider, called *Araneus nauticus*, which wove a 22-inch web across a Himalayan pool. In so doing it emitted 122 feet of silk thread, made 699 attachments, and travelled over a distance of 178 feet—the whole work taking only thirty-six minutes.

Major Hingston has probably seen more different kinds of instinctive behaviour than any other living naturalist, and his conclusions must receive every consideration. One of them, one that commends itself to us, is that intelligence not infrequently intervenes when instinctive routine is endangering the creature's life. Another, but one which we cannot accept, maintains that instinctive behaviour has evolved from intelligent behaviour that has become automatized. The facts of heredity seem to us to be quite against this interpretation of instinct as *lapsed intelligence*; and there are other great difficulties, such as the extreme and remorseless inflexibility that instinctive behaviour often exhibits. It is often so fatal that it seems to us to tell against Hingston's theory that 'instinct began in a reasoned act.' If it did, how is it in many cases impossible or extremely difficult to awaken any hint of the originally intelligent learning? But Mr. Hingston's answer is that the automatization has become so thorough that it

cannot be departed from, and he gives many illustrations of this. Thus, keeping to spiders, he tells us of one, called *Sparanus lutescens*, which makes a very neat spiral nest out of a blade of grass, and fixes its egg-bag inside. Hingston took out the egg-bag or cocoon and placed it on a free part of the grass-leaf in the hot sun. The spider could have retrieved it in a moment; it was only half an inch away; some related spiders rise to the occasion at once. But what this particular species does is to shoot out threads of silk and fasten the cocoon in the glare—which is rapidly fatal. 'A creature can fashion that elegant spiral, yet it has not the wit to pull its egg-bag inside. When anything happens to go wrong with her egg-bag, all she can think of is anchor and fix. Pulling would require a slight gleam of originality, and her instinct is too limited for this.'

INTELLIGENCE OF A WASP.—An observant correspondent sent us a description of a wasp's effective behaviour. He saw it catch a blue-bottle inside the window-sill and fly off with it to the top of the window, which was slightly open. But there was an in-current breeze and exit was baffling, especially as the breeze caught the blue-bottle's wings. Several times the wasp failed and the blue-bottle tumbled on to the sill. After a few failures (the number not recorded) the wasp cut off the victim's wings and flew off successfully, having reduced the friction of its burden. Our correspondent asked whether such an instance does not prove Reason; and, if not, why not?

Our answer is that the use of the word 'reason' in such a case is much too generous, if we are to use words in a precise scientific way. Since comparative psychology became more exact it has been usual to keep the word 'reason' for the mental process of experimenting with general ideas or concepts—for 'conceptual inference,' in short. When a man builds a bridge in a difficult situation and works out a plan that requires some very clear-headed thinking—in many cases mathematical—he is illustrating Reason; but there is no convincing evidence that any animals ever rise to this level. The nearest approaches are on the part of anthropoid apes, horses, dogs, and elephants; but the cleverest behaviour of the cleverest animals does not usually lead us to credit them with more than intelligence, i.e. perceptual inference, experimenting with mental images and the like. They do not work with general ideas or concepts. We ourselves in our everyday life are oftener intelligent than rational, and so it is, but more so, with the cleverest animals. They may show reasoning or inference, without attaining to Reason; just as they often have words without attaining to language. The marvellous skill exhibited at a sheep-dog trial is a supreme illustration of intelligent behaviour, but our admiration, to be just, is bound to take account of the education of the collie by the shepherd and by its own kith and kin. To return to the wasp

and the blue-bottle fly, it may be already plain that the biggest word we dare use is 'intelligent,' and that it would be far too generous to speak of Reason. The scientific rule is to try to describe behaviour with the simplest hypotheses, and it is simpler to credit a creature with intelligence or perceptual inference than to assume the operation of reason or conceptual inference. It is plain, however, that the simpler interpretation will have to be rejected if it does not adequately describe what happens.

An instinct, as we have seen, is an inborn power of doing apparently clever things, and while it is probably accompanied by some measure of awareness and endeavour, it is physiologically near a chain of intricate reflex actions, such as we illustrate in coughing or sneezing or swallowing, or in closing our eye at the approach of a missile. The routine of a flower-visiting insect is often like a chain of reflex actions, but there are reasons for crediting the ant or the bee with some mental activity, such as enjoyment and endeavour, associated with its busy automatism. Moreover, there is ample evidence that instinctive routine may be sometimes interrupted by flashes of intelligence that save the situation, as when a spider adjusts its web to a particularly difficult situation.

Now it is well known that wasps, and hornets in particular, often cut off the wings of their insect-booty. We have seen one biting off the wings and the limbs of a daddy-long-legs or crane-fly, thus making the booty more manageable. Since this is a common piece of behaviour, it may perhaps be regarded as part of the instinctive repertory, and if so, the only spark of intelligence on the part of the wasp that we began with may have been in bringing the inborn predisposition into operation under somewhat unusual circumstances. Our verdict would be: *largely instinctive, but with a spice of intelligence*. But more observations are needed before we can interpret the case with a clear intellectual conscience!

ANIMALS AT SCHOOL.—We may 'feel quite sure' that a dog or a horse of our acquaintance can draw a conclusion, but it is not very easy to prove this. The higher animals are quick to take a hint; they have good memories, but can they put two and two together? Is their behaviour really intelligent? Have they any sense of relations?

It does not follow from the effectiveness of what an animal does that it has intelligence. There is no use pretending that we can call the building of nests and the weaving of webs *intelligent*. They are the outcome of inborn *instinctive* capacities, which are mainly independent of any 'learning' or experimenting, and are apt to be upset, sometimes rather ridiculously, if there is the least interruption of the usual routine. They have not the 'smack' of intelligence, though they reveal an inborn inspiration for efficiency which remains a puzzle.

But, away from instinct altogether, dogs and cats, horses and elephants are certainly able to go a long way in establishing associations, and this is apt to make them seem more intelligent than they are. Lord Avebury's dog Van would, as the result of training, fetch a card printed 'TEA' when there was a prospect of this refreshment; but this kind of efficiency is not as 'intelligent' as it looks. There is, we believe, far more evidence of intelligence in the behaviour of a clever collie shifting a flock of sheep from one field to another. A mediocre dog bungles the business and exhausts the flurried sheep; a real expert exhibits what seem to us intelligent tactics.

Various experiments have been devised in order to test whether higher animals can be said to think. Cats have been put in puzzle-boxes in order to discover how soon and how tenaciously they learn the trick of getting out; rats have been tried in mazes to discover whether they can profit by experience in an intelligent way; and many other methods have been used.

One of the latest has been devised by Professor R. M. Yerkes, who wrote a very interesting book on *The Dancing Mouse*. He made a dozen identical boxes, each with an entrance door at one end, and an exit door at the other, and he could raise or lower the doors by means of weighted cords. A reward was hidden under the exit door of a chosen box, which might be the first at the left end of a group (Problem 1), or the second from the right end (Problem 2), or first the one and then the other in regular alternation (Problem 3), or the middle box (Problem 4). The boxes were presented in varying groups to individual crows, rats, and pigs, in order to discover whether the creature could form any idea of *furthest to the left, second from the right, or middle.*

If the animal chose a wrong box it was imprisoned for a while, and after liberation was allowed to choose again. If it chose the right box it got the reward, and returned to the starting-point for another trial. When the reward was in the first box at the left end of the group, crows learned in from 50 to 100 trials to stick to that box. But when the reward was in the box second from the right end of the group of boxes (Problem 2), the crows failed to improve in 500 trials. They were alert and keen, but seemed unable to profit by experience in an intelligent way. Not that they chose quite at random, but they did not learn to choose rightly. In our language, they could not get at the idea of *second from the right*. White rats were less on the spot than crows; they took from 170 to 350 trials to fix their choice on the first box at the left end. They made nothing of the second problem. Pigs solved the first problem with 50 trials or less, the second problem in from 390 to 600 trials, the third—left and right end alternately—in about 450 trials; but they could not fix their mind on the idea of *a middle box*. Yet the pig was so far an easy leader.

In subsequent experiments Dr. Yerkes tried two monkeys and an orang-outan. A rhesus monkey proved itself 'alert, business-like, intent on his task.' He solved the first problem in 70 trials; he quickly and regularly got rid of his mistakes.

An irus monkey was erratic, easily discouraged, and took 132 trials. The orang-outan was 'child-like in his desire for assistance, as also in his resentment of annoyances or disappointments.' He was given to settling down to a simple routine; thus for over a week he persisted in choosing the box nearest to the starting-point. To stop this it was arranged that the nearest box was *never* the right one. For a few days no improvement was made. 'On 10th May, in a series of ten trials, seven were incorrect, but the following day and thereafter only correct choices appeared. Thus, suddenly and without warning, the ape solved his relational problem.'

This is very interesting, for it is difficult not to believe that between the poor performance on 10th May and the perfect performance on 11th May the orang-outan did a little mild thinking. One remembers similar experiences oneself; one suddenly saw through a problem. The rhesus monkey solved the second problem in 400 trials, the irus monkey in 1,070 trials, the orang-outan failed utterly in 1,380 trials, and after that he 'followed the path of least resistance.' One suspects that he was not sufficiently interested to try hard. But when a banana was hung from the roof of his cage he tried various ways of getting at it, and when the experimenter showed him that this could be done by stacking boxes on the top of one another, he did this readily.

Neither of the monkeys made systematic efforts to obtain the banana, and when they were shown how to do so they did not imitate their teacher. Given a pole which reached the banana, the ape quickly secured the prize with few useless movements. But the monkeys never used the pole at all. The ape drew food into his cage with a stick; the monkeys never attempted to use it. This shows a great difference between the monkey and the ape. Though the irus monkey was not much of a scholar, he was a bit of a mechanical genius. He used a lock and key with great satisfaction, and he used to drive nails with a hammer into a board, and then draw them out and begin again.

INTELLIGENCE OF CHIMPANZEES.—Since Professor W. Köhler made his careful observations at Teneriffe, naturalists have had to raise their estimate of chimpanzee intelligence.

Great ingenuity was displayed by the chimpanzees in solving practical problems, such as reaching a banana fixed to the roof by piling one box on the top of another, sometimes to the number of four; or retrieving some fruit out of reach beyond the bars of the cage by fixing a small bamboo rod into the cavity of a larger one; or making

levers for breaking boxes and bolts; or fashioning a spade for digging and a stick for fighting. The chimpanzees not only used simple tools, they made them. Not less interesting than the achievements are the limitations. Chimpanzees are inventive when they get a visual grasp of the whole situation, but they seem to have a very slender capacity for 'image-forming.' They work cleverly with the materials that are before them, but out of sight is out of mind. Another great handicap is their poverty of speech. Perhaps a dog has a larger vocabulary, or even a rook. Though they were for a time delighted with a hand-mirror, and were ingenious in finding other mirrors for themselves, even puddles of rain-water which they contemplated with great intentness, they never showed evidence of getting away from the conviction that there was an elusive 'other fellow' through the looking-glass. Many were the efforts they made to catch him napping, but he was always too nimble.

PLAY IN ANIMALS.—At the height of summer all who can lay down their tools, and many who can't, begin to think of holidays. Yet in the animal world summer is the season of intensest industry. The photosynthesis that goes on in green leaves is at its climax, and that means an abundant manufacture of foodstuffs, sufficient not only for the needs of the plants, but for the sustenance of all ordinary animals as well, whether they are vegetarian or carnivorous. Thus summer is the time of intensest industry because there is a maximum of energy, available for transformation. From another point of view we may say of many living creatures, both plants and animals, that they have to work hard in summer accumulating reserves that help to keep them from dying in winter. Even an annual has to work for the next generation, providing some sort of legacy.

But if summer is characteristically the season of industry, it is also the time when play is most in evidence. And this is no contradiction, for play implies surplus energy, plenty of food, comfortable surroundings, and the tonic of sunshine. Moreover, the young creatures of the springtime are now vigorous enough to strike out for themselves in the adventure of life.

We are more or less familiar with play in kittens, puppies, young otters, young foxes, young stoats, lambs, kids, calves, foals, squirrels, leverets; but it finds expression in many other mammals, such as young water-shrews and monkeys, and in some birds also; witness the sedate penguins of the Antarctic.

It is difficult to draw the line, but true play has usually a particular form for particular types; it is to be distinguished from random frisking about. It approaches art. It is usually restricted to youth, but there are some mammals that never lose their playfulness. Thus the otter is said to play throughout life, on to the very gates of death.

There are many different forms of play, characteristic of different animals. The sham-hunt is illustrated by kittens chasing the wind-blown withered leaf in the garden or the ball of worsted in the room. The sham-fight is often well illustrated by puppies and young bears. The sham-race is seen in lambs and calves, and in the former there is sometimes what looks like 'tig.' Lambs often indulge in a sort of 'derring-do' game, in which one shows off to its fellows by walking along a narrow ridge in the pasture or by climbing a height. In

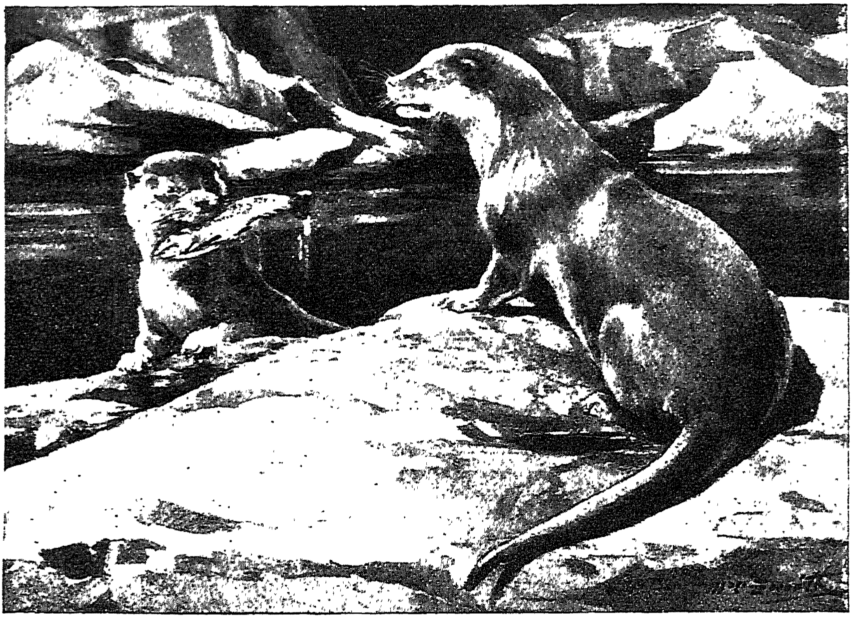

FIG. 309. OTTERS

many cases the play seems to be a sporting adventure. Thus penguins will mount on a floating block of ice and allow themselves to be quickly swept by the tide through a narrow strait. At the far end they jump off, swim or waddle back to the starting-point, and there begin again. Monkeys and apes often show a similar taste for 'sport'; and Mr. P. G. Hamerton records of the young goats which he studied carefully that they changed their fun from day to day as circumstances suggested. The important fact is that the forms of play are very varied, though at the same time never random.

By definition, play is emphatically for fun, and yet it must have

biological justification of some sort, else it would not have found persistent expression in so many different types. Four converging rays of light help to illumine the problem of the significance of play. The first suggestion, which is useful up to a certain point, is due to the poet Schiller and the philosopher Herbert Spencer. It regards play as the expression of surplus energy and overflowing animal spirits. But this does not explain why the play-activity takes definite forms in particular types, the kitten's so different from the puppy's.

The second suggestion is due to the psycho-biologist Groos, who seems to have been the first to recognize the obvious fact that play is the young form of work. The nature of the play, which is now instinctively developed, though sometimes helped by imitation, has been gradually defined in reference to the kind of activity that is characteristic of the type in its adult life. The hunting animal plays at hunting, the climbing animal at climbing, the pugnacious animal at fighting; and so on, all along the line. The play period is an invaluable apprenticeship during which the playing animals are helped towards proficiency before mistakes are of serious moment. It is an irresponsible preliminary canter before the real race begins. Moreover, a superstructure of intelligent learning may sometimes be seen to rise on a foundation of instinct.

A third suggestion, emphasized by Ammon, is also illuminating. The play period affords opportunity for testing new departures or variations in behaviour. The ways of animals would not be so subtle as they are unless there had been through long stretches of time crop after crop of novelties in behaviour; and these are still emerging. These new departures have to be tried and tested, and the play period offers opportunity for sifting these before the struggle for existence has set in too severely. Play gives a variation in behaviour some elbow-room, some chance to be criticized generously. Among most domesticated animals, such as sheep, horses, and cattle, the pressure of circumstances is usually too strong, and the playful lambs, foals, and calves have to settle down to very staid conventionality. Man has rather a knack of nipping buds. But it can hardly be doubted that in Wild Nature the play period has had an important rôle in allowing elbow-room to advantageous new departures in behaviour.

A fourth indirect utility of the play-activity of such animals as those we have mentioned is that it provides an education in 'give-and-take.' Especially for social and gregarious creatures, it is important that they should learn to adjust themselves to one another, not keeping to an 'each-for-himself' policy; in short, it is by playing that playful animals are helped to learn to 'play the game' in a wider sense.

Now, what applies to play in animals applies also, *mutatis mutandis,*

to play among children. Human play is, of course, more subtle, but the biological interpretation is useful in emphasizing the radical value of a form of activity which some have hastily regarded as trivial. For children as well as for young mammals play is a safety-valve for overflowing energy and high spirits; it is a joyous apprenticeship to the serious work of life, which asserts itself soon enough; it is a precious opportunity for the outcrop and testing of individualities and originalities; and yet it is a discipline in self-subordination and teamwork. Good players usually make good workers and good citizens. Let us play when we can, so that we may work well when we must.

The Feelings of Animals

In old days people used to speak of the three sides of their nature sa head, hand, and heart; and it is still convenient to speak of the intellectual, the practical, and the emotional sides of our life, if we remember at the same time that the three aspects often blend. When a mathematician is solving a problem he is intelligent. When the coolies are coaling a ship they are practical, though their efficiency depends not only on their muscles, but on their good humour and on their elimination of useless movements. When we are enjoying the scenery of a new country we are largely emotional, though we may think we enjoy it more when we know something of its geological significance. The head, the hand, and the heart often thrill together and strengthen one another; though it is also a familiar experience that a man's heart may be stronger than his head.

It is evident that 'feeling' is one of those innocent-looking words that are very troublesome because they are used in a variety of ways. A great number of its uses come to the mind at once:

I have such a strange feeling that I was in this place once before, long ago.
He did not show much feeling for his friends.
He did not shrink from hurting their feelings.
There is a feeling of winter in the air.
Jefferies had a strong feeling for Nature.
I cannot tell why, but I have a feeling that something is going to happen.
But, doctor, I have such a sinking feeling when I go out for a walk.

And so we might continue feeling our way into the meaning of feeling. If we wish to know how animals stand as regards feeling, therefore, we must first try to separate out some of the many uses of the word, or we shall get very badly bogged.

Lowest on the inclined plane, we think, is what may be called **irritability.** By irritability the physiologist means the capacity of

responding to a certain stimulus. He does not mean mental irritation or crossness: he means sensitiveness to certain influences.

Thus the sensitive plant is irritable when we touch its leaves with our finger; the tendrils of the pea and the vine are irritable when they come in contact with a twig. The sea-anemone's tendrils show irritability when they are touched with a fragment of flesh, and the earthworm answers back to the tremors in the soil produced by the light footstep of a blackbird. Man shares with animals many of these irritabilities, and in many cases is far behind the animal — even behind the plant — in his sensitiveness.

Sir Jagadis Bose tells us that when he was once experimenting in his laboratory on the reactions a plant was giving to a certain provocation, he was puzzled by a change in its irritability, though the conditions in the laboratory appeared to him to be constant. Looking up, however, he saw that a wisp of cloud was drifting across the face of the sun, and *it was this that the plant had felt*!

Man has perhaps a greater range of irritabilities than any single animal, but in any one direction he is surpassed by many other living creatures. Thus his sense of smell is far behind the dog's, his sense of touch far behind the bat's, his sense of hearing far behind the hare's, and so on. Two things must be noted, however. In the first place, a response to a stimulus proves the irritability of the living matter in most animals; but this can hardly be called a feeling unless there is evidence of the creature being aware of its experience. A starfish has many irritabilities, for instance, but as it has no nerve-centres nor anything like a brain it hardly deserves to be credited with any **sensations.** In the second place, not only do many animals and plants surpass man in their sensitiveness to particular kinds of stimulus (ants and bees, for instance, see the ultra-violet rays to which we are blind), but it is quite probable that some other living creatures may feel influences which are ignored by us. It is difficult not to credit the way-finding birds with some sense of direction that is only hinted at in a man.

On a different plane from irritabilities and sensations are what may be called **appetites,** such as hunger and thirst, and the *urge* of sex. These we share with the animals, though their expression is necessarily more subtle in us than in them.

Man's nature is so complex that his appetites have become wrapped up with emotions and ideas, traditions and ideals; and it is bad science as well as bad practice to speak and think and deal with human beings in a physical sense as if they were merely one class of the higher mammals. Just as it is wrong to pretend that a living creature is no more than a whirlpool of matter and energy, so it is wrong to pretend that man is no more than a mammal. One of the outstanding facts

of evolution is the increasing prominence of the mental aspect as we ascend from lower to higher animals, and it follows from this that what is physical in us becomes more and more closely linked to psychical affection. Fondness rises into love, as we say.

Similarly, in regard to the appetites of hunger and thirst, they are fundamentally alike in man and beast; yet they are far more subtle in man. Among well-to-do people in civilized countries the appetite of hunger is unfamiliar, and very few know what thirst really means. Among animals the primary appetites are much more forceful, and this fact should be kept in mind in judging them. Moreover, even when a civilized man is really hungry or thirsty his satisfaction of these appetites tends to be restrained by ideas and conventions, often with considerable subtlety. Our forefathers, whose meals were usually irregular and often coarse, had to satisfy their hunger when they got a chance, and so they tended to eat too much. Nowadays among educated people gluttony is rare. But we are not pretending that man has lost the risk of parting with his birthright for a bowl of red pottage.

It is a common usage to speak of man's instincts, but we regard this as a mistake. By instinctive behaviour the naturalist means the outcome of an inborn power of going through an effective routine without training. It is true that we do not require to learn to cough or to sneeze, but these are only single actions, not links in a chain of behaviour. We cannot walk instinctively, as a moorhen swims. But, leaving aside this question of instincts, on which opinions differ, we certainly share with higher animals a number of deep-down instincts, such as self-preservation, and a certain amount of kin-sympathy, and a desire to be on good terms with them if other things are equal. This is often called the instinct of the herd; and it is well known that many social animals, from ants and bees to wolves and monkeys, will cordially help their own kith and kin, and give the cold shoulder to strangers. Our proposition is that many animals are like men in being born with certain deeply rooted promptings, which may be illustrated by a feeling of kinship and by a sense of self-preservation.

By 'feelings' people usually mean the **emotions,** which are states of mental excitement, neither intellectual nor imaginative, with reactions in many parts of the body, such as the heart, the lungs, and the ductless glands. Among the fundamental emotions we count fear, anger, and love; among the subtler emotions jealousy, cruelty, and foreboding. What we are considering is how animals stand as regards the emotions.

Some people take a very sceptical attitude and point out that we cannot get inside an animal and prove that it is joyous or unhappy, sympathetic or envious. The answer to that extreme niggardliness was given by Darwin long ago, when he showed that in similar conditions the same gestures, movements, sounds, and other expressions

are seen in similar animals, that they recur with great consistency, and that many of them resemble those seen in man in similar circumstances. A man's sneer may be something like a dog's snarl. The 'glad eye' in the best sense is seen in many a joyous mammal welcoming a friend or an owner.

Unless we are willing to make Animate Nature an illusion we must admit that many animals have emotions, often at a high level, as in the nightingale's lyrics. As for proving things, is it easy to *prove*, for instance, that a thwarted man is full of the emotion of anger?

We have seen a male antelope bullying an upstart, which sought in vain to escape from a terribly severe punishment. The junior had been badly mauled, gored in at least half a dozen places, and was streaming with blood. We had not any doubt as to the reality of the anger on the one hand, or the fear on the other. In some highly evolved animals these emotions may be stronger than in man, for the simple reason that the creatures let themselves go. They are not checked by moral considerations or by social conventions.

Other things being equal, the higher animals tend to be swept away by emotions more readily than men, just because they do not think much, and because, in spite of their many virtues, they do not know the meaning of *ought*. They have the raw materials of morality, but they are rarely moral. They do not control their behaviour by reference to ideas and ideals, or social commandments.

The emotions or feelings common among higher animals are anger, some form of love, fear, some form of joy, emulation, and, in some cases, a pleasure in being with their kindred. But, while these may be very strong, they are much less subtle than the corresponding emotions in man. Many animals show fear, but it is improbable that they have much in the way of anticipation or dread except in regard to circumstances of which they have had much experience. Perhaps Walt Whitman was right in saying that over all the earth no wild animal is unhappy; and though there may be grim moments of violent death there is little looking forward to them, and they are soon over. We once timed a golden eagle's killing of another bird; the tragedy occupied twenty seconds, and unconsciousness probably followed the first clinching of the talons.

We think that many of the higher animals give clear signs of being moved by the simpler feelings, such as affection and anger, gladness and sadness, sympathy and aggressiveness, but that it is wise to refrain from reading the man into the beast too generously. Bower-birds like pretty things, but it is going a long way to credit them with artistic feelings, or what we call the aesthetic emotion. Many dogs enjoy fun, but we do not agree with our friend who credits his fox-terrier with a sense of humour. There is no doubt that some animals, such as

elephants and peafowl, resent affront and seek retaliation, even after an interval has elapsed; but it is probably going too far to speak of an animal's revenge. Revenge means a clear purpose of retaliation, and a keeping of this purpose in one's consciousness. It means not only nursing wrath to keep it warm, but planning to get even with the enemy. Animals do not rise to these heights.

The strutting peacock seems to the uncritical observer to be overflowing with vanity, and the dog with its tail between its legs to be covered with shame, but the probabilities are that these interpretations imply an over-generous reading of the man into the beast. Perhaps it is wiser to be content with the idea that many animals have, like children, a stream of feelings which succeed one another like April showers.

On the other hand, we must not be too mean in our estimate of the emotional life of animals, for there are occasional hints of subtlety among them. In a most careful study of chimpanzees Professor Köhler notes that they may combine in fury when one of their number has been punished in their presence; but that they took his side when he had to speak sharply to some human intruders. 'I told them firmly that they must go away,' he says, 'but in vain; the animals began to pay attention. I called to the people sharply, and the whole group of apes shrieked with indignation. I shouted at the hesitating intruders, and all the chimpanzees jumped howling against the bars at them.' On very rare occasions it happened that one of the chimpanzees would side with the professor and against its fellows. Strikingly subtle, also, is their expression of what we should call wounded feelings. A young female ape persisted in snatching food out of the hand of a weaker ape, and Professor Köhler gave her a slight rap, and he writes that: 'The little creature, which I had punished for the first time, shrank back, and uttered one or two heart-broken wails, as she stared at me horror-struck, while her lips were pouted more than ever. The next moment she had flung her arms round my neck, quite beside herself, and was only comforted by degrees, when I stroked her.'

This 'need for forgiveness' has also been recorded of dogs.

We often speak of a feeling of pain, but it would be more accurate to speak of a sensation, unless indeed we are using the word 'pain' metaphorically, as when we say that it gives us great pain to read such bad verse. As regards the sensation of pain among animals we must avoid two extremes. We must not read ourselves into the beasts of the field, whose susceptibilities are much less. The callousness some uncivilized people show in regard to wounds and burnings and scourgings is well known; and even among ourselves some people are much less sensitive than others. In some cases there is a mental factor, of anticipation, of fear, of preoccupation, or of fussiness; and this is

probably almost entirely absent in the animal except when associations have been formed. The dog does not smile when it sees the familiar whip, but it does not lie awake at nights thinking about the punishment it deserves.

Among some of the big-brained mammals there is considerable evidence of a sense of pain. They wince, they struggle, they run away, they utter cries. They recoil often as we do in jerking away our hand from a hot cinder, or our bare feet from a sharp tack; but there is often more than this, as is seen when a reminder of the cause of pain awakens symptoms of distress. Except when there has been very frequent repetition, this dread discloses a mental factor, a true memory of pain.

The sensation of pain is probably in direct ratio to the elaboration of the nervous system, and there does not seem to be much evidence of its acuteness among the lower backboned animals or among the backboneless animals. A professor of theology who has a high standard of veracity told us that he once made a clumsy jerk when angling and tore out the eye of a trout. He cast again, in his anger with himself, and the trout took the hook that bore its lost eye! If our friend had not been a professor of theology we should not have dared to tell this fish story, but of course it must be true; and while it indicates that the glittering object on the hook pulled the trigger of the seizing instinct, it suggests that the sense of pain is not acute in fishes.

It is well known that a wasp, a highly strung creature, will continue sipping jam although part of its body has ceased to exist; and a driver-ant will remain busy for more than an hour although its body has lost the whole of the region behind the narrow waist. It seems very improbable that there can be any real pain in animals, like starfishes, that are without a centralized nervous system.

We must be careful not to let this possibility weaken our reluctance to injure any living thing. Our scorn of all wanton destruction of harmless lower animals need not be much lessened even if it be certain that no pain is felt. The harm that we do in hurting an animal may be more to ourselves than to the creature. We are uselessly destroying a thing of beauty, an antique, a fellow-creature, a member of the kingdom of which we are trustees. Unless the destruction is in the interests of higher life we are doing what is ignoble; and this seems a stronger basis for humane treatment than the suggestion that we are inflicting pain. It was, we think, this deep humanity that led Wordsworth to write these lines:

Never to blend our pleasure or our pride
With sorrow of the meanest thing that feels.

Personality among Animals

To some people it may seem outrageous to speak of personality among animals, for personality is man's proud prerogative. Let us agree to differ, then, about the best word to use, if we may agree on the important fact that many animals show something *analogous* to personality in ourselves. Many animals give us glimpses of a unified self, with remembered experience and with an individual character. We recognize them, and they us, as fellow-creatures. More than a touch of nature makes us kin. We may surely say this without surrendering anything of man's splendid, though often latent, apartness from the rest of creation.

Miss Alyse Cunningham tells us of 'John Gorilla,' whom she educated, that when she was waiting to go out one day the young ape expressed a wish to sit down on her lap. He was a sensitive, affectionate child. But as she happened to have on a light dress, her sister advised her to say 'no' to John: for though he got to like being very clean, he was sometimes a little dusty. When John was pushed away, he lay down on the floor and cried, just like a child, for about a minute; then he got up, looked round the room, and picked up a newspaper, which he proceeded to spread over Miss Cunningham's lap. After which, of course, he had to be allowed his seat of honour.

Now this behaviour may not have been quite so clever as it looked, but it *was* clever; and it was also what we call 'human.' The ape-creature was meeting the human creature; there was, we venture to think, considerable mutual understanding. The gorilla showed the beginning at least of personality; and our plea is that we should be more generous in looking out for this in animals.

It is bad science, of course, to read the man into the beast without any scruple, for that leads to a Brer Rabbit Natural History which is hopeless. Yet it is also bad science to recoil from the generous 'man in the beast' view, so violently that the loving animal is thought of as if it were an automatic machine. The line of sound description is between these two extremes. A squirrel is a delightful animal to study and to make friends with, but what we wish to get at, is not our reflection in its eyes, but the squirrel's mind looking out on us. We need not expect to find reason looking out of the squirrel, but we shall certainly find intelligence, good feeling, and resolute endeavour.

It must be admitted, however, that some animals are more approachable, more responsive, more intelligent, and more intelligible than others. Thus it must be very difficult to get alongside of a whale, though many a man has made close friends with another mammalian giant—the elephant. We once became very friendly with a golden

eagle, but all our cajolings of a solan goose or gannet proved futile. We have known a crow descend from a height on to the shoulder of a man who had befriended it through hard times; but did any one ever gain the confidence of a boa constrictor? Every one has heard of modern analogues of Androcles and the lion, but did any one ever become friendly with a salmon? A robin is a distinctly companionable bird, perhaps with some awareness that man's aegis is over it (long live the pleasant superstition!), but we could not get a water-rail, for instance, to open a door—not even a grille—to our friendliest overtures. We began by saving its life, as a matter of fact, but we were not even tolerated. Some creatures seem almost hopelessly entrenched in shyness and suspicion.

It is easier to get alongside a very clever animal, for it meets you half-way. You can make much more of a rat than of a hedgehog. It is easier to become intimate with a playing mammal, such as a fox, otter, or squirrel, than with one that does not play. We remember being agreeably surprised by the notable friendliness of a *Hyrax* or 'coney' which the Secretary of the Zoological Society used to take with him on his shoulder to the meetings of learned societies. It is easier to establish sympathetic relations with an animal that shows much intelligent behaviour than with one that is in the main a creature of instinct. Yet we know what a depth of sympathetic insight was reached by Fabre in his studies of insects, which no one can think of as responsive, so thrilled are they by their predominantly instinctive promptings.

Granted that there are great differences in the approachability and responsiveness of animals and in our sympathies towards them, we venture to plead for increased generosity in our outlook on the animal world. There is no homunculus lurking in the toad; yet even it does sometimes contrive to send out tendrils of recognition to its human friend. Without sentimentality, but with patience, may we not discern in many an animal more of a kindred spirit than we are at first inclined to admit as possible? Even if we do not find evidence of intelligence, or of putting two and two together, we may find good feeling and the raw materials of morality. Even if we do not find almost any clear evidence of an inner or psychical life at all, may we not recognize a deep unity in the fundamental 'urges' of hunger and love, which are the prime motives of organisms from the beginning to the climax of organic evolution? Even if the true inwardness of the creature evades us entirely, may we not find common ground in the essential sameness of the bio-drama from first to last? Would not some such vision make it almost impossible to be cruel to a creature?

Personally we have no scruples in eating an oyster alive, or a Brer Rabbit (the hare) dead; we enjoy them both barbarically and heartily.

Personally we have no scruples about killing the rat and likewise its flea. But we have scruples—that is to say, self-contradictions—in inflicting avoidable pain, other than that (if any) associated with instantaneous death; and we have scruples about the *ruthless* destruction of any form of life—whether large or small—for every one of them, as Walt Whitman says, is a masterpiece for the Highest. The path towards an increased reverence for life is through a fuller recognition of personality among animals. In short, we wish to recapture from the poets—from Burns to Masefield, for instance—a sympathetic appreciation of the common animals of the country.

Perhaps we miss our reward sometimes by thinking too much of the intellectual side of mind and forgetting the surge of feeling and the bent bow of endeavour.

The realm of animal life is crowded with virtues, as may be seen especially among birds; who shall complain if there is independence as well as kin-sympathy, the close-girt loin as well as the merry heart? We do not mean that the best of them are 'ethical agents,' controlling conduct in reference to an ideal; *that is man's way*. But we see the springs of goodness in the mother stoat protecting her offspring against the gamekeeper and his dog; in the father hornbill wearing himself thin in his efforts to support his family; in the patience of the brooding bird; in the stickleback protecting his nest against intruders ten times his own size, and in the self-subordination of the worker-ants and bees—extreme as that often is.

One point more. There are many animals that we cannot get near mentally. We cannot breathe their atmosphere of instinct, having ourselves comparatively little in the way of instinctive behaviour. We cannot talk their language and they do not give us any token that they regard us as fellow-creatures. Perhaps we are only moving hillocks to animals like spiders. Yet when we study a spider's web we recognize a fellow-craftsman. Personality will out. In the strict sense, we suppose, animals cannot have art—if art be the expression of ideas in significant form. But perhaps they have emotional art and in any case they are often consummate craftsmen. When we study any notable triumph of life over matter, any defiant conquest of material difficulties—the spider's web across the stream, the gossamer spiders ballooning through the air, the mother trap-door spider sinking her shaft, plastering its walls, constructing a neatly fitting lid with a silken hinge, all for the sake of her offspring—we have a vicarious pride and we join hands even with the arachnid. Our artistic taste is different from that of the bower-birds, but, after all, do we not sit down at the same beauty feast?

When we come down to the simple creatures, where the inner life cannot be more, so far as we can understand, than a very slender rill,

may not the beauty of the body itself be an expression of a dormant personality? We are thinking of creatures like corals and zoöphytes and the true plants of land and sea. We know that in mankind the 'temple face' is sometimes 'chiselled from within.' Perhaps the hidden beauty of Venus's flower basket (a Deep-Sea flinty sponge) is a hint of a dreaming mind, working with materials, of course, which obey laws of surface tension and what not. But so is it with every artist. There are laws and limitations for every medium.

When we come face to face with humble creatures that give us little or no aesthetic thrill, their beauty being *difficult*, we can perhaps find a common ground in discerning the drama of their life—always caring for self and caring for others just as we do ourselves. If we get to know earthworms, for instance (with Darwin's help, who gave them his attention from boyhood to old age), we see them moved by 'hunger' and 'love,' conquering difficulties and engaging in adventures; we see them altering their ways from age to age, and changing the world more than any other animals have done. And then we have to think of the worm as a stage in the ascent of that mysterious kind of activity which we call life. With Emerson we must picture the worm 'mounting through all the spheres of form, striving to be man.' With Darwin, we venture to say, we can see a deeper meaning than even Blake discerned in Job's words: 'I have said to the worm, Thou art my mother and my sister.'

Our plea is for a generous, well-informed discernment of the personality among animals, for that is the way to get beyond cruelty, beyond the vulgarity of calling any whole creature common or unclean and beyond every possibility of being bored as long as we can see the everyday creatures of the country.

CHAPTER VII

SEX AND HEREDITY

Reproduction and sex—Development—Heredity—Modes of inheritance—Species and specificity—Individuality—What are genes?

Reproduction and Sex

Living creatures stand apart from not-living things in their powers of growing and multiplying or reproducing; and with the reproduction there is in the majority of cases associated the fact of sex. This means that two physiologically different types (the males and the females) produce the two kinds of reproductive units, the sperm-cells and the egg-cells respectively. The fertilization of the egg-cell by the sperm-cell is followed by another characteristic feature of living creatures, namely **development,** which means the expression or actualization of the inheritance so as to form first an embryo-organism, and then a young organism, and then the full-grown form. Before we go on to illustrate reproduction, we wish to say a little about growth, which is its prelude. Reproduction is to be thought of as primarily *discontinuous growth*; in its simplest forms it implies separating off some surplus material.

MODES OF REPRODUCTION.—When a single-celled organism divides into two units which separate from one another, when a planarian worm divides crosswise into two worms, when a rare starfish separates its five arms each of which proceeds to grow an entire animal, when a liverwort liberates a minute fragment or gemma which is washed away by the rain and starts a new plant elsewhere, when a bulbil falls off from a tiger-lily, and so on, we have to do with **asexual reproduction.** The characteristic feature is that the offspring arise not from special reproductive units, but from detached pieces of the parent. It is a somewhat expensive mode of multiplication; it produces only a few offspring at a time; they are apt to inherit defects that are exhibited by the parent's body; and there are other disadvantages.

But when the offspring start from special reproductive cells or germ-cells, we have to do with **sexual reproduction.** In most cases these special reproductive cells are the mutually dependent ova and spermatozoa, but they may be **spores,** whose characteristic is that they do not require any fertilization, and are *in that sense* asexual. It is clearer, however, to rank them as specialized reproductive cells

which do not require to be fertilized. We *deliberately* rank spore-formation as a mode of sexual reproduction.

When the ova are produced by one kind of individual and the sperms by another, then clear-cut **sex** is illustrated. When the female individual or egg-producer is notably different in detail from the male individual or sperm-producer, then there is **sex dimorphism,** so familiar in peahen and peacock, in hind and stag.

It often happens that the essential male organs (the testes) and the essential female organs (the ovaries) occur normally in the same individual, though they are in many cases ripe at different times, and this state of affairs is called **hermaphroditism.** It is well illustrated by earthworms, leeches, and snails, which are normally hermaphrodites; but it does not occur above fishes except as an abnormality or freak. Some animals, such as the little starfish called *Asterina gibbosa,* pass through a hermaphrodite stage, and change from being bisexual to being unisexual.

In some animals and in a few plants the egg-cell develops without being fertilized. This is **parthenogenesis,** as in rotifers and dandelions. But a little clear thinking will show that this must be included under sexual reproduction. Although the males and male elements are not needed, the offspring develop from specialized reproductive cells—the ova. The queen-bee produces eggs that require fertilization (developing into workers and queens) and others that need no fertilization (developing into drones).

In plants also there are egg-cells and sperm-cells, and fertilization occurs as in animals, but in the flowering plants the true ovaries and testes (or spermaries) are so well hidden away that it required a genius to discover them. The reproductive cells which are produced by the stamens and carpels correspond to the **spores** which are so well known in ferns and related flowerless plants. In another section we have tried to explain how the spores in flowering plants, namely, the pollen-grains produced by the stamens and the embryo-sac produced by each carpel, give rise to the almost suppressed male and female generation, from which in turn there arise the true sperms and ova.

In typical sexual reproduction in animals there are, then, two dimorphic and physiologically different types of individual in each species—the males producing spermatozoa in testes, the females producing ova in ovaries. A spermatozoön enters into intimate orderly union with an ovum, and this fertilization leads to the segmentation of the fertilized ovum and the development of an embryo. It is theoretically unimportant whether the egg-cells are liberated and fertilized outside of the mother's body, as in the frog, or whether they are fertilized and proceed to develop inside the body as in mammals.

Similarly, it is theoretically unimportant whether the spermatozoa are liberated on or near the ova, as when the male salmon sheds his *milt* (seminal fluid) on the eggs shed by the female into a furrow in the gravelly bed of the stream, or whether they are passed by the male into the genital duct of the female, as in mammals. The essence of sexual reproduction is the formation of two different kinds of reproductive units, the **gametes**; and these are in the majority of cases produced by two different individuals, the males and females, and in different kinds of reproductive organs (or **gonads**), the testes and the ovaries.

USE OF TERMS.—It is important to use terms in a precise way, not calling a spade a shovel. When two of the higher animals begin, say at the breeding season, to keep company, we say that they are *mating*. If they proceed to attract one another's attention and interest in some special way, as in song and dance, we say that they are *courting*. When they come together sexually, as one flesh, we say that they are *pairing* or *coupling*; and when there is actual transference of the seminal fluid from the male into the female there is *insemination*. The process of sexual union is also called *copulation* or *coition*; but coupling is a good old English word. The transference of pollen, often with an insect's help, from the stamens of one flower to the pistil of another of the same kind, is *pollination*. The term *fertilization* should be kept for the intimate, orderly union of the sperm-cell and the egg-cell, and this is usually a microscopic business. The term *impregnation* is practically confined to mammals; it implies that fertilization has followed insemination; development has begun and the mother is said to have *conceived*. Very different is the word *parturition*, which is applied to the birth of the young creature which has been developing within the mother during the period called in mammals the time of *gestation*. The liberation of ova from the ovary is *ovulation*.

ADVANTAGES OF SEXUAL REPRODUCTION.—The various activities summed up under the term 'sexual reproduction' are often very intricate and exhausting. In some cases, from sea-worms to fishes, if not higher, sexual reproduction involves the death of the maternal parent or of both parents. What are the advantages which have, in the course of millions of years, given practical justification to variations in the way of fostering and improving sexual reproduction, instead of adhering to the asexual mode?

(1) Sexual reproduction tends to be physiologically less expensive than the asexual method of liberating fractions or fragments or buds of the body.

(2) Sexual reproduction often allows of the production of many offspring at the same time which may be a particularly suitable season.

(3) Sexual reproduction involves the pooling of two different inheritances, paternal and maternal, and this may result in useful averaging or in provoking variations.

(4) Sexual reproduction greatly lessens the risk of the offspring starting with a handicap of defects or taints from the *body* of the parent.

(5) Sexual reproduction is associated in many cases with a strong urge towards the bodily satisfaction which follows the discharge of the sex-cells. This urge is often so imperious that the occurrence of reproduction is ensured.

(6) Sexual reproduction often acquires an emotional tone, which has been a mainspring of conjugal affection.

THE EGG-CELL OR OVUM.—Every multicellular organism, whether plant or animal, if reproduced in the ordinary way, begins its life as an egg-cell, which is usually fertilized by a sperm-cell or its equivalent.

An egg-cell is usually small, a common diameter being one-hundredth of an inch. But it may become large by the accumulation of non-living nutritive material or **yolk.** When we speak of an egg, we include not only the cell proper, but its envelopes and accessories like yolk.

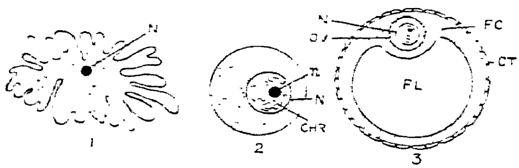

FIG. 310. EGG-CELLS

1. Primitive amoeboid egg-cell, with nucleus (N).
2. Typical egg-cell or ovum with nucleus (N), nucleolus (*n*), and chromosomes (CHR).
3. Mammalian ovum (OV) with nucleus (N), surrounded by follicle-cells (FC). FL is the cavity occupied by the *liquor folliculi*, or follicular liquid. CT, surrounding cells of the ovary.

An ovum has the usual characters of a cell. There is the colloidal cell-substance, partly protoplasm and partly inclusions; there is the **nucleus** or **germinal vesicle,** containing the **chromosomes** which carry the initiatives of the hereditary characters, or some of them; and there is the external membrane, the **vitelline membrane.** In many cases, as in *Hydra,* the young ovum is amoeboid, but becomes more spherical and compact as it grows older and acquires reserve material and a surrounding membrane.

The yolk consists of a protein (vitellin) and a fatty substance (lecithin). It comes in various ways into the egg-cell—from adjacent cells (as in *Hydra*), or from yolk-glands (as in the liver-fluke), or from the maternal blood (as in higher animals). It may be abundant or sparse, and disposed in various ways—diffusely throughout the ovum, or towards one pole, or in the core. When an egg is large (as in sharks, crocodiles, and many birds), it always implies the presence

of much yolk. The amount of living matter remains small. Round the unfertilized egg-cell there is a delicate film, the vitelline membrane. When fertilization occurs, this becomes lifted up from the cytoplasm and much more distinct, sometimes becoming thicker and firmer. This is known as the **fertilization membrane.** If the egg-cell becomes bloated with yolk, as in birds, there is formed a **vitelline capsule,** a multicellular envelope of connective-tissue cells, strong enough to resist some strain.

Neighbour cells may form a **follicular membrane** around the ovum, as in Ascidians; or a non-living **egg-shell** may be produced from special shell-making glands which are often situated on the wall of the oviduct down which the eggs pass on their way to liberation. This egg-shell varies in its nature; thus in insects it consists of chitin, in the skate and its relatives of horn or keratin (forming the 'mermaid's purse'), in birds of calcium carbonate. When it is formed *before* fertilization, as in insects, it shows a minute aperture (the **micropyle**) or several apertures, through which the spermatozoön finds entrance. The hard shells familiar in birds' eggs are formed in the oviduct *after* fertilization, and so in similar cases. Egg-shells are to be distinguished from **egg-cocoons** or **egg-capsules,** as in earthworms, spiders, whelks, which enclose several ova wrapped up together.

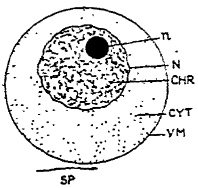

FIG. 311. DIAGRAM SHOWING RELATIVE SIZE OF A TYPICAL OVUM AND TYPICAL SPERMATOZOÖN (SP); N, nucleus; *n*, nucleolus; CHR, chromatin; CYT, cytoplasm; VM, vitelline membrane.

THE SPERMATOZOÖN.—Most spermatozoa are very minute cells, invisible without a microscope, sometimes only one-hundred-thousandth the size of a pinhead-like ovum. In most multicellular animals they are markedly adapted for locomotion, for they have to swim in the water or in the female genital duct in search of the ova. It is a constitutional obligation — a **tropism** (q.v.) — on their part to swim against a gentle current, or in a spiral, or round and round in varying orbits. In some females among Vertebrates, e.g. in turtles, it has been shown that rows of cells in the oviduct produce upward and downward currents, the former assisting in the upward passage of the spermatozoa.

A typical animal spermatozoön shows: (1) an anterior 'head,' consisting mainly of chromatin; (2) a locomotor 'tail' whose undulations drive the head along; and (3) between the two, a middle piece, which contains a centrosome. The 'head' contains the initiatives or **genes** of the hereditary characters; and the number of chromosomes in the ripe spermatozoön is usually the same as in the ripe ovum.

The spermatozoa of threadworms and most crustaceans are sluggish and approach the amoeboid type. In threadworms there is insemination and the sperms are wafted up the genital duct to meet the ova as they pass down. In most crustaceans the sperms are deposited by the active male on the eggs carried by the active female, else fertilization would not be likely to occur. But in the fixed barnacles and acorn-shells, included among crustaceans, the sperms are of the usual type. Among the flowerless plants the fertilizing unit, the spermatozoön or **antherozoid,** is typically a multiciliate cell, suited for rapid movement in water and for making its way into the female organ (archegonium) where the egg-cell lies. But in flowering plants the counterpart of the spermatozoön is a generative nucleus formed in the pollen-tube to which the pollen-grain gives rise. This generative nucleus divides into two, and one of them unites with the egg-cell inside the embryo-sac. It is a mistake to make a direct comparison between pollen-grain and spermatozoön, for the pollen-grain is a **spore** which gives rise to an almost suppressed sexual generation—the nuclei in the pollen-tube.

A very interesting discovery was that the Cycads and the *Ginkgo* (maidenhair tree), which are primitive seed-plants, have multiciliate spermatozoa or antherozoids, like those of ferns, horsetails, and most cryptogams. The pollen-tubes of the old-fashioned plants we have mentioned give rise to swimming sperms. A typical animal spermatozoön has little cytoplasm in proportion to nucleoplasm. In other words, the ‘ head ’ consists almost wholly of chromatin, which becomes resolved inside the fertilized egg-cell into a definite number of chromosomes, the bearers of the paternal inheritance.

Since the spermatozoön may be very active in its movements, it is a relatively katabolic unit, with much expenditure of energy and little income. In most cases it is short-lived, and that is not surprising. But in some cases it may retain its vitality for a long time—e.g. for a couple of years inside an inseminated queen-bee. In a few cases, as in horses, the sperms can be used to effect **artificial insemination.**

A spermatozoön is often called a ‘ male cell,’ and of course it is produced by a male, and in its katabolic preponderance it is a sort of symbol of maleness. But it must be clearly understood that it may initiate a male *or* a female individual. Similarly, an ovum, often called a ‘ female cell,’ may develop into a male *or* into a female.

MATURATION.—Almost universal in the history of the egg-cells of animals is a process known as maturation. When the egg-cell is ripe, its nucleus moves to the periphery and gives off half of itself—the **first polar body.** This is effected by the rare kind of cell-division which is called **meiosis** or **reduction-division,** in which the number of chromosomes is reduced by a half. This polar body, a dwarf sister-cell of the ovum, comes to nothing, though it occasionally divides in the ordinary

way into two. Having reduced itself, the nucleus of the ovum repeats the process, giving off the **second polar body.** But this is effected by the ordinary karyokinetic type of division or **mitosis,** in which each chromosome is longitudinally split down the middle. Thus the giving off of the second polar body does not imply any further reduction in the number of chromosomes. The reduced nucleus of the ovum then retreats to the centre of the events, and awaits the fertilization, which may or may not occur.

Now in the divisions that give rise, in the testis of the male animal, to numerous spermatozoa, there is a similar reduction, most often in the last division but one. Thus if n be the normal number of chromosomes, the ripe sperm-cell has $\frac{n}{2}$ and the ripe egg-cell $\frac{n}{2}$. In fertilization the normal number is restored, for $\frac{n}{2}+\frac{n}{2}=n$. An analogous process of reduction occurs in plants.

FERTILIZATION.—Fertilization is the union of two sex-cells, or gametes, to form a **zygote,** which proceeds to develop into an embryo. In ordinary cases among multicellular animals it is the union of the liberated dimorphic sex-cells—the ova and the spermatozoa. In the *Protozoa* two unicellular individuals may entirely fuse to form one, and this is called **total conjugation,** as in sun animalcules (*Heliozoa*) and many others. Or two Protozoa may become closely apposed and exchange portions of the nucleus, a **partial conjugation** which has been much studied in the slipper animalcule (*Paramecium*). From such cases, and from others where the conjugating units are dimorphic, the transition to fertilization in multicellular animals, by means of sperms and ova, is not difficult.

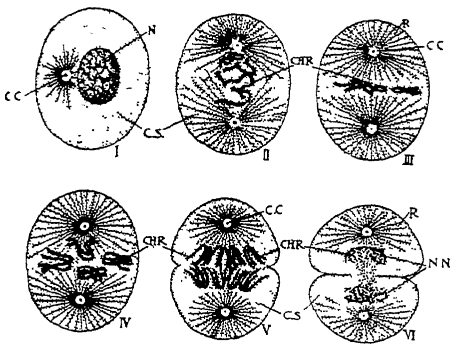

FIG. 312. ORDINARY CELL-DIVISION (*Mitosis* or *Karyokinesis*)

CC, centrosome; CHR, chromosome; CS, cytoplasm; N, nucleus in resting stage; NN, nuclei re-forming; R, rays.

Fertilization in ordinary Metazoa may be defined as the intimate and orderly union of the reduced nuclei of two dimorphic cells—a spermatozoön and an ovum. As we have explained, the meaning of the word 'reduced' in this connection is that in the process of forming

and ripening the two kinds of sex-cells there is a halving of the number of chromosomes. It will be clearly understood that it is in this microscopic process of fertilization that almost all multicellular organisms begin their individual life. In a typical case among animals fertilization (see Fig. 313, p. 977) implies the following events:

(1) There is a combination of the maternal and the paternal inheritance, mostly at least carried in the chromosomes of the ovum and the spermatozoön respectively. The chromosomes are closely apposed, but they do not fuse.

(2) There is some stimulus, perhaps of the nature of a ferment, conveyed to the egg-cell by the sperm-cell. The result is that division or segmentation begins.

(3) A sudden change in the ovum, following the entrance of the sperm-cell, usually blocks the way to the entrance of others.

(4) As the sperm-cell penetrates the ovum it leaves the locomotor tail outside, but it seems to introduce a centrosome which divides into two, and plays a part in the subsequent division. The ovum centrosome, often visible in the immature cell, seems to disappear. But some authorities insist that the entrance of the spermatozoön evokes a *de novo* formation of a centrosome in the ovum, and that there is no introduction along with the head.

(5) The normal number of chromosomes is restored, the half number being furnished by the two reduced gametes—the ripe ovum and the ripe spermatozoön.

PECULIARITIES IN SEXUAL REPRODUCTION.—In most animals there is a liberation of egg-cells from the female. The conger eel liberates over a million ova in the sea; the golden eagle lays two eggs in its eyrie; the *Sepia* fastens its bunch of 'sea-grapes' to the seaweed; the earthworm buries in the soil a little capsule or 'cocoon' of eggs; the frog leaves her spawn in the ditch. These are instances of the common egg-laying or **oviparous** method. But at many different levels in the animal kingdom the fertilized egg-cell develops inside the mother, and it is a young creature that is subsequently liberated—the **viviparous** method. It has the obvious disadvantage that only a few young ones can find room to develop inside the mother; but it has the obvious advantage that the young develops in safety, and may be sheltered for a long time (sometimes more than a year) before it is set free to fend for itself.

One might collect some interesting examples of this viviparity—e.g. a viviparous freshwater snail (*Paludina*), a viviparous sea-anemone, a viviparous green-fly or Aphis, a viviparous blenny from the seashore, a viviparous lizard. All mammals are viviparous except the primitive duckmole and the spiny ant-eater, which lay eggs like their reptilian ancestor. Flowering plants are viviparous, for the liberated seed is

already a young plant. We may say that one of the trends of evolution has been towards viviparity.

In not a few cases, as we have mentioned, an animal is normally hermaphrodite, that is to say, it produces both ova and sperms. Snails, earthworms, leeches, barnacles, ascidians are familiar examples. Hermaphroditism also occurs in the hag (*Myxine*), in a few bony fishes (species of *Chrysophrys* and *Serranus*), and in a solitary amphibian; and this does not include numerous cases where it occurs casually or abnormally.

In most cases of hermaphroditism, the **bisexual** animal produces ova at one time and sperms at another; and this is technically called **dichogamy.** In most cases, moreover, there is cross-fertilization, for while a snail is hermaphrodite and highly sexed (as its Cupid's dart suggests), it does not fertilize its own eggs. Of two pairing snails, A inseminates B, and B inseminates A. In rare cases a hermaphrodite animal fertilizes its own eggs, as in flukes and tapeworms, and this is called **autogamy.**

We do not know, but we suspect that some hermaphrodites (e.g. barnacles and one species of oyster) have evolved from ordinary **unisexual** types, while other kinds, e.g. planarian worms, were primitively hermaphrodite.

Crossing is sometimes successful between individual organisms that are not very nearly related, but the likelihood of its occurrence is in inverse ratio to the difference between the two individuals. It is called **hybridization,** and within a narrow range, namely between varieties of one species, it often occurs in Nature. When the range is narrow it is called cross-breeding, out-breeding, or exogamy. It seems to provoke new departures or **variations** in the offspring, and some biologists believe that it has been of great importance in the course of evolution. Sometimes the attempt at crossing is entirely unsuccessful, as between hare and rabbit; sometimes it is effected, but without offspring; sometimes there are offspring, but they are sterile, as is usually the case with mules; but sometimes there are fertile offspring, as in the hybridization between American bison and European wild ox, between Indian humped cattle and domesticated ox, between common goose and Chinese goose, between common duck and pintail duck, between different species of pheasants, between wolf and dingo, and in many backboneless animals.

There is occasionally a successful crossing between different genera, as between domestic fowl and pheasant, and between quite different sea-urchins. Oftenest, however, it is between different varieties or breeds of one species. Pairing of near relatives or **consanguinity** is very common in Nature and, contrary to a widespread view, it does not seem to have prejudicial effects unless there is some deterioration in

one or both of the parents. Within a narrow range it is called inbreeding or endogamy, and it tends to give new characters a firmer hereditary grip. It has been of much value in establishing some of the domesticated breeds and races, as in polled Angus cattle and scores of similar cases.

When the descendants of one parent, as in garden peas and slipper animalcules, or of two parents in a few experiments, are kept apart, the descendants form what is called a **pure line** or **clone**, in which there tends to be very little in the way of germinal variation.

Xenia is the name applied to a strange phenomenon, best known in maize, when the pollen from the male parent appears to influence not only the embryo, which develops from the fertilized ovum, but the surrounding tissue. When a pollen-grain begins to develop on the stigma of the flower, it sends out a pollen-tube which grows towards the egg-cell within the ovule, within the ovary. In this pollen-tube there is a vegetative nucleus, which has to do with the tube itself, and there is a generative nucleus, which divides into two. One of these unites in an intimate orderly way with the egg-cell within the embryo-sac, the result of this fertilization being the development of an embryo-plant. In some cases, such as maize, the other generative nucleus from the pollen-tube unites with another nucleus or with two nuclei within the embryo-sac, and the result of the fusion has to do with the development of the endosperm, i.e. nutritive tissue around the embryo. When the white-grained maize (*Zea alba*) is pollinated from the blue-grained variety (*Zea cyanea*), most of the seeds have white endosperm, but in some it is blue. This looks as if one of the generative nuclei from the pollen fertilized the egg-cell as usual, while the other fertilized the nucleus that has to do with endosperm development.

Development

WHAT DEVELOPMENT MEANS.—Nothing is more characteristic of living creatures than their power of individual development, from a simple beginning in a fertilized egg-cell, a spore, or a fragment, to the full-grown adult. Out of apparent simplicity (though it is really a treasure-box filled through past ages) there develops obvious complexity. A drop of living matter lying on the top of the yolk of a hen's egg undergoes differentiation and integration, and gives rise to a chick. **Differentiation** is the structural side of division of labour, it means increase of complexity. **Integration** means unification, harmony, control, for the many cells and parts that arise by the division of the initial egg-cell (or whatever the germ may be) are somehow bound together into a well-controlled individual organism. Development always means progressive differentiation and integration, and this is a

deep problem. The one cell becomes many, the latent becomes patent, the invisible visible, the embryo a full-grown organism; and so it is through the world of life.

HOW THE INDIVIDUAL BEGINS.—Even down to the days of Sir Richard Owen (1804–92) there was a widespread persistence of the old belief that living creatures could arise from appropriate non-living matter, insects from a carcass, gordian worms from horse-hairs, and internal parasites in man from nothing in particular. This was the theory of present-day **spontaneous generation** (**abiogenesis**)—a false view that has died hard. The disappearance of the belief was assisted by the invention of the microscope, which made it possible to trace many puzzling organisms back to their invisible origin as egg-cells or minute germs of some sort. Very important also were some crucial experiments, like those of the Italian Redi, which showed that maggots do not appear in flesh that is carefully surrounded with muslin—for the muslin keeps the mother blow-fly from laying her eggs in the flesh. In such ways there was a gradual establishment of the conclusion that all living organisms that appear to-day take their origin from parental organisms of the same kind. Whatever may be true in regard to the dim and distant past, there is no evidence of spontaneous generation in present-day conditions.

In the single-celled animals, or *Protozoa*, multiplication usually comes about by the individual dividing into two daughter-units or into many. When there are many they are called spores. Half of a protozoön may have to do a little in the way of development before it becomes a replica of its parent, if we can speak of 'parent' in such simple cases. The spores are often so very simple that they have to develop considerably before they become replicas (or reproductions, we may say) of the original unit. In many cases, however, there is *more growing than developing*. It will be understood that these simplest animals do not usually get beyond being unicellular; only in a few exceptional cases do they divide into a number of coherent daughter-cells, giving us a hint of the way in which many-celled animals—with a **body**—might begin (see PROTOZOA). Much the same might be said in regard to the simplest plants (see the Introduction to Part II).

Among plants spores are common, from lowest to highest, but there is in the majority of cases an alternation between a spore-producing generation (e.g. the ordinary fern plant) and a gamete-producing generation (e.g. the fern prothallus). (See ALTERNATION OF GENERATIONS.)

In animals, however, spore-formation is unusual, and the development usually begins, as has been explained, in a fertilized egg-cell. Asexual reproduction lingers here and there among animals, up to the Ascidians or Tunicates, and is well illustrated by the budding of

hydroids, the division and budding in corals of many kinds, the halving of simple worms, the colony-making of the moss-animals or *Bryozoa*, and in some other cases.

EARLY STAGES IN DEVELOPMENT.—The fertilized egg-cell divides into two, four, eight, and more cells, after a pattern which depends

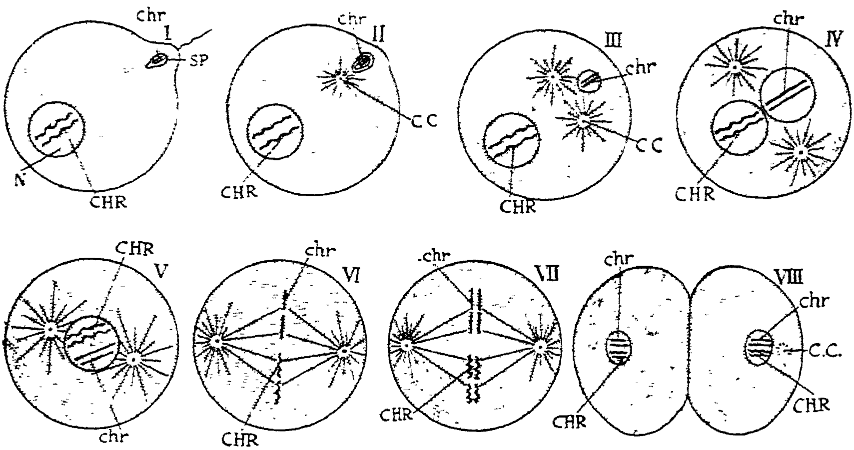

FIG. 313. DIAGRAM SHOWING FERTILIZATION AND THE FIRST CLEAVAGE

I and II show the spermatozoön (SP) with two chromosomes (Chr) entering the ovum, the nucleus (N) of which also coantins two chromosomes (CHR).
III and IV show the formation of two centrosomes (CC).
V and VI show the centrosomes with rays or 'archoplasmic threads' radiating outwards in part to the chromosomes of the two fused nuclei.
VII and VIII show stages in segmentation during the first cleavage. Note that each new nucleus contains four chromosomes, i.e. half of each chromosome originally present in the nuclei of the ovum and spermatozoön.

mainly on the amount and arrangement of the yolk. This first chapter is called **cleavage** or **segmentation.**

(1) It may be total and equal, when the yolk is sparse and uniformly distributed, as in starfish and in ordinary mammals.

(2) It may be total and unequal, when there is a considerable amount of yolk, sunk to the lower pole, as in the frog.

(3) It may be partial and discoidal, when there is much yolk, on the top of which the living matter lies, as a transparent disk, like a watch-glass turned upside down, as in birds and reptiles. The segmented disk is called the **blastoderm.**

(4) It may be partial and peripheral, when the yolk is all in the centre, and the living matter is spread all round it, as in insects and most crustaceans.

The result of the segmentation of the animal ovum varies with the type. It may be a hollow ball of cells, the **blastula**, as in sea-urchins; or a solid ball of cells, the **morula** (like a mulberry), as in the frog; or a disk of cells, the **blastoderm**, as in most fishes.

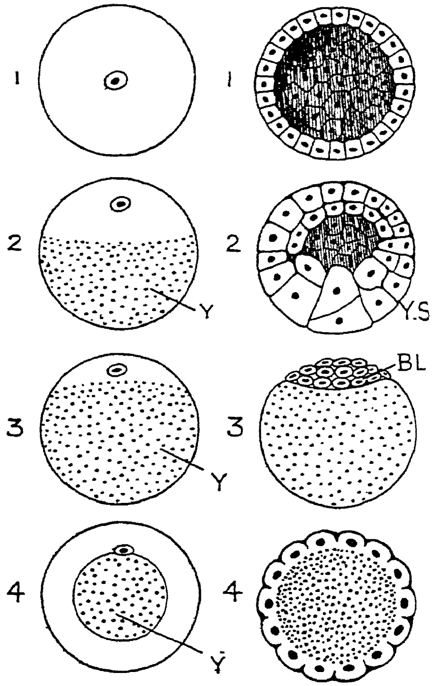

FIG. 314. DIAGRAM OF AN EGG-CELL, SHOWING DIFFERENT MODES OF CLEAVAGE

1. Ovum with little yolk, segmenting wholly and equally into a hollow ball of cells (*blastula*), e.g. sea-urchin.
2. Ovum with more yolk (Y), segmenting wholly but unequally, as in the frog; *morula* type. YS, larger, yolk-laden cells.
3. Ovum with much yolk (Y) towards lower pole, segmenting partially and discoidally, forming *blastoderm* (BL), as in birds.
4. Ovum with much central yolk (Y), segmenting partially and peripherally, as in crayfish.

Then growth begins to set in, and at unequal rates, the result being the establishment of the **germinal layers**—the **ectoderm** or **epiblast,** the **endoderm** or **hypoblast,** and (from worms upwards) the **mesoderm** or **mesoblast.** When there is a blastula like a hollow ball, it is often followed by a typical **gastrula,** as in the starfish and lancelet (*Amphioxus*). As the result of unequal rates of cell-division and growth, one hemisphere of the blastula becomes surrounded by the other, and the result is a two-layered thimble-shaped stage—the typical gastrula. For a time it has only two germinal layers, the ectoderm and endoderm; after a while, and in various ways, the mesoderm appears between the two. The endoderm of the gastrula lines a cavity—the **archenteron**—which will develop into the digestive part of the food-canal. The mouth of the gastrula is called the blastopore; it corresponds to the future mouth of the animal, or to the anus, or, curiously, as in *Peripatus*, to both.

Immature ovum, called the **ovarian ovum** as long as it remains in the ovary; **ovulation,** the liberation of the ovum from the ovary, often by the bursting of a nest of cells or **follicle**; the process of maturation, or the formation of the polar bodies; fertilization;

segmentation; the establishment of the germinal layers—these are the early chapters in development.

Then follows the **differentiation** of tissues and organs, a process still beyond our understanding. Differentiation is the structural side of division of labour. Out of the apparently homogeneous there appears the obviously manifold—nerve and muscle, food-canal and skeleton, and so on.

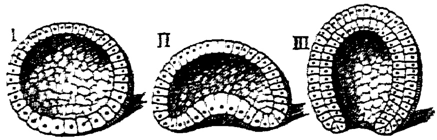

FIG. 315. STAGES OF FORMATION OF GASTRULA IN *Amphioxus*

I, blastula or blastosphere stage, cut in half; II, gastrulation beginning by invagination; III, young gastrula in longitudinal section.

If we compare the fertilized egg-cell to a double bag of seeds of many different kinds, we may fancy that different samples of seeds are sown in different cells as the cell-divisions proceed. But the facts do not support this theory. It looks rather as if a complete (and double) sample of seeds was sown in each plot or cell; some find expression or development, others do not; this depends on the soil and exposure of the plot, i.e. on the composition and surroundings of each cell. In any case differentiation occurs.

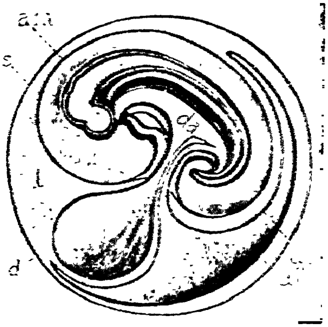

FIG. 316. DIAGRAMMATIC SECTION OF EMBRYO-CHICK WITHIN THE EGG

D, yolk-sac; *d*, wall of yolk-sac; *da*, gut of embryo; *al*, *al'*, inner and outer walls of the allantois; *am*, amnion; *d*, amniotic cavity; *s*, sub-zonal membrane; *l*, extra-embryonic body-cavity into which the allantois grows.

EMBRYO AND LARVA.—It is usual to keep the word **embryo** for the developing organism as long as it remains inside the egg-envelope or egg-shell and is obtaining its food passively from the yolk or the like. Thus the developing chick is an embryo as long as it remains unhatched within the egg-shell, and the developing frog is an embryo as long as it remains within the envelope of jelly.

It should be understood that an egg-cell may divide into, say, thirty-two cells without becoming any larger, for the individual cells have not yet begun to grow. But in many cases, as in the chick within the egg-shell, or the skate within the 'mermaid's purse,' the embryo has grown relatively large before it is hatched or before it has taken a morsel of food into its mouth. The embryo is unhatched, unable to feed itself, unable to do much in the way of movement.

When the embryo develops within the mother, and is relatively

well advanced before it is liberated, it is called a **foetus.** This term is especially applied to the viviparous mammals, where there is a placental union between the developing embryo and the wall of the maternal oviduct. An unborn kitten or puppy, foal or lamb is a foetus.

What emerges from the egg-envelope or egg-shell may be a miniature of the adult, as in the case of a chick, and it should be called a young creature or young organism. But in many cases what emerges is very different from either embryo or adult, it is a **larva,** which is adapted to live an independent life, feeding actively, fending for itself. It cannot put on the adult characters without some drastic change or **metamorphosis.** As good examples we may mention:

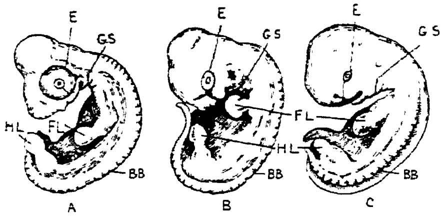

FIG. 317. STAGES IN THE DEVELOPMENT OF A VERTEBRATE EMBRYO

E, eye; GS, gill-slits; FL, fore-limb buds; HL, hind-limb buds; BB, backbone.

A caterpillar, so different from the butterfly or moth.

A tadpole, so different from the frog or toad.

A free-swimming tadpole-Ascidian, so different from the sedentary adult.

A *Nauplius* or later stage, so different from a barnacle or acorn-shell.

An Open-Sea free-swimming *Pluteus,* so different from the sea-urchin.

A flattened transparent 'glass-crab' or *Phyllosome,* so different from its parent the rock-lobster (*Palinurus*).

What is the meaning of these larval forms, which are very different both from the embryos and the adults? They represent a chapter *interpolated* into the life-history, and adapted to secure particular results, such as:

(1) Widespread distribution, beyond the adult's scope.

(2) The getting away from a haunt that is difficult for the young and tender life, as when the larval shore-crabs are hatched out some distance from the shallow water, and live for some time in the relatively easier Open Sea.

(3) The accumulation of nutritive capital, so that the adult can afford to do with little food, as in the case of the voracious caterpillars that make the ascetic, but reproductive, butterflies possible.

(4) The attainment, in some cases, of a relatively large size, as in the caterpillars which grow quickly; they have to face the moultings from which the adult higher insects are exempt.

(5) The weathering of certain seasonal difficulties which the adults could not face; as in the burrowing larvae of some beetles.

(6) The securing of foothold for the species by being multitudinous, and well able to stand thinning, as in the case of tadpoles as compared with frogs, and elvers as compared with eels.

RECAPITULATION.—The individual animal develops along a path the stations of which correspond in some measure to the steps of ancestral history. The developing animal seems sometimes to be climbing up its own genealogical tree. The rabbit begins like a Protozoön, as a single cell; it becomes a ball of cells, like some of the colony-forming *Protozoa*; this is followed by a two-layered stage, which might be compared to one of the very simplest multicellular animals, such as *Microhydra*. So far, perhaps, there is not much recapitulation in the true sense, for beginning as a single cell simply means that there is sexual reproduction, and we do not know of any way in which an egg-cell can develop except by successive divisions. But as we follow the developing rabbit there is more convincing evidence of recapitulation, especially in the making of the various organs (**organogenesis**). For a while the developing embryo is like the young stage of a simple Vertebrate; then it is like the young stage of a higher Vertebrate; afterwards it is comparable to the embryo of almost any mammal; afterwards to the young of rodents in general; and eventually it is unmistakably a young rabbit. **Ontogeny** (the development of the individual) tends to be a condensed (though distorted) recapitulation of **phylogeny** (the evolution of the race). It does so because the individual life begins in an implicit *organization* (in the egg-cell) which is the outcome of steps taken by many generations of ancestors. In development the implicit organization becomes explicit—the egg becomes a chick.

Heredity

WHAT IS MEANT BY HEREDITY?—When a very important post has to be filled, those responsible for the selection usually inquire into the education, record, and health of the various candidates, and sometimes when they have their eye on a likely one they say to one another: 'But let us also look into the man's heredity.' Perhaps that is not the best use of the word, but what the electors propose is plain enough; they wish to inquire into the candidate's parentage and ancestry, for they know that it means much to come of a good stock, and, on the other side, that some taints or defects are very apt to persist from generation to generation.

Heredity is the relation of genetic continuity between successive generations. Or, if this definition is too difficult, we may say that

heredity is a name for the arrangements which make like beget like, or tend to beget like. Heredity is the relation between successive generations that depends on the germ-cells, which are the vehicles of the life that is continued. Heredity secures the persistence of a specific organization, and we say the same thing when we use the old words: Men do not gather grapes of thorns or figs of thistles. Heredity is the hand of the past which makes like tend to beget like.

THE CONTINUITY OF GENERATIONS.—In some way that we cannot picture, all the essentials of the future organism, except what it gains by experience, lie in the fertilized egg-cell. The initiatives or possibilities are all there, but they have to be helped to express themselves by 'nurture,' which includes all the influences of food, surroundings, and activities. In the language of the old parable, the 'talents' —whether two or ten—are given in the inheritance; but it is open to the individual organism—whether plant, animal, or man—to increase them by trading. So far as is known, it is not possible to acquire a new talent which is not represented by an initiative or bud in the inheritance; but it is, on the other hand, certain that it is in our power to strengthen the talents we inherit, or, on the other hand, to let them remain undeveloped if we do not use them or care for them. Somehow or other all the initiatives or buds lie in the microscopic germ-cell, seldom as large as a pin's head, and many of them at least lie in the nuclear rods or chromosomes. Thus the study of heredity must greatly concern itself with the germ-cells, for they are the vehicles of the inheritance, and they secure the continuity of generations.

A strawberry plant sends out a long horizontal *stolon* or runner which grows for a foot or so close to the ground, and then anchors itself, gives off roots and a rosette of leaves, and *a new runner*. This may repeat the process, and we occasionally find a chain of three or four strawberry plants, separated by intervals, and yet united by a runner. This may serve as an image of the continuity of generations; but the successive generations are, of course, in most cases physically separate from one another, and the continuity is kept up not by an asexual runner (though there are interesting stolons in some colony-forming animals) but by the germ-cells.

What typically occurs is this, as Professor Weismann and Sir Francis Galton first clearly showed. When a fertilized egg-cell divides into daughter-cells and forms an embryo with division of labour or differentiation, some of the cells do not share in the body-making, but remain like the fertilized egg-cell. As development goes on, the body-cells or somatic cells become nerve-cells, muscle-cells, gland-cells, and so forth, but the undifferentiated cells form the reproductive organs and multiply there. In due time, in typical cases, some of the germ-cells are liberated from the reproductive organs and start the

individuals of a new generation. Since they have retained the initiatives present in the fertilized egg-cell that developed into the parent, they are able to develop in the same general way. Thus *like begets like*.

CONTINUITY OF THE GERM-PLASM.—An early isolation of the reproductive cells or germ-cells, directly continuous with and therefore much the same as the original ovum, has been observed in the development of some 'worm types' (*Sagitta*, the arrow-worm of the Open Sea; threadworms, such as *Ascaris*; leeches, *Polyzoa*); of some Arthropods (e.g. *Moina* and *Cyclops* among Crustaceans; *Chironimus*, the harlequin-fly, among Insects; *Phalangidae* among Arachnids); of some fishes, e.g. *Micrometrus aggregatus*; and in a number of other forms.

In many cases, however, the reproductive cells as such are not recognizable until a relatively late stage in development. Weismann got over this difficulty by supposing that in such cases the continuity is sustained by a specific nuclear substance—the **germ-plasm**—which remains unaltered in spite of the differentiation of the body, and may even be carried in cells that have themselves undergone considerable differentiation. As all the cells of an organism are descendants of the fertilized ovum, it is perhaps enough to say that the reproductive cells or germ-cells are those which retain the qualities of that fertilized ovum, and that this is the reason why they are able to develop into offspring like the parent. In plants and in simple animals like hydroids, which are very like plants in many ways, there is probably diffuse germ-plasm in most of the cells of the body, and it is not for a long time in many cases that distinct germ-cells are visible.

HEREDITY AND VARIATION.—Heredity, as we have explained, is not a power, or a force, or a tendency; it is a relation of continuity between parents and offspring, or between ancestors and descendants—a continuity which is brought about by the germ-cells. We can hardly cease using such phrases as, 'he handed on his eloquence to his son,' or, 'he transmitted his lack of control to his children,' but they are not really quite accurate. For the parent does not exactly *make* the germ-cells, being rather their trustee. A fertilized egg-cell gives rise to an organism, and to the germ-cells thereof. But these germ-cells have variability, and a particular change which occurs in them may be carried farther in the offspring and in its germ-cells. Thus, though it may seem at first a hard saying, heredity includes **the possibility of variation.** The general tendency of the reproductive arrangements which we sum up in the term 'heredity' is to secure the persistence of a specific organization; but heredity does not exclude variability. It is not clear thinking to make a contrast between 'variation' or the origin of novelties, and 'heredity' or the persistence of sameness, the first being divergence and the second inertia. The true contrast is between complete hereditary resemblance

and the outcrop of something novel; and heredity includes them both.

MODES OF INHERITANCE.—When two similar animals are paired, the offspring may be practically indistinguishable from the parents. This is **complete hereditary resemblance**, and it is sometimes seen in true-breeding domestic animals, such as sheep, pigs, white mice. But when we have an intimate acquaintance with these animals, we usually find minute differences or individualities which we did not notice at first.

When two similar animals are paired, the offspring may be markedly different from either parent, or from any known ancestor. It may be a **mutation** or **variation**, in some respects distinctly novel. A child may be born without any superficial pigment, or it may grow up a calculating boy; a kitten may be born with long 'Angora' hair, though there is no illustration of this in any cat in the neighbourhood; a greater celandine may suddenly appear with all its leaves cut up (laciniate).

These are the two extremes—complete hereditary resemblance and a marked mutation. Between these there are other modes of inheritance. The first of these is **blended inheritance**, when the offspring are, in one character, or it may be in several, intimate mixtures or averages of the two parents. Thus 'half-bred' sheep are the very useful results of crossing two quite different parents, usually Cheviots and Leicesters. When a lop-eared rabbit with long ears is crossed with a lop-eared rabbit with short ears, both true-breeding when paired with others like themselves, the result is a litter whose lop-ears, when fully grown, are precisely an average in length between the ears of the two parents. It has been recorded for some nearly related plants that the offspring may show an exactly blended inheritance as regards the hairs on the leaves, the number of stomata, the length of style, and so on.

Sometimes an appearance of blending may be accounted for in terms of Mendelian inheritance (p. 987), when a particular character like stature, or the colour of the skin, is found to be due to the combination of a number of separate hereditary factors. Thus, though the skin-colour of a mulatto *looks like* a blend of the white colour and the black colour of the two parents, this is not the theory which Mendelism suggests. The same would be true in regard to what may be called coarse-grained or particulate inheritance, of which a piebald pony is a good instance. In rare cases a man or a sheep-dog shows the maternal eye on one side of the head, and the paternal eye on the other.

It occasionally happens that a calf developing horns is born in a pure-bred hornless breed of cattle like the polled Angus. This 'harking back' to a distant ancestor is called **reversion**, and the

word **atavism** is perhaps best regarded as a synonym. Those who have tried to distinguish the two have unfortunately stated the difference in exactly opposite ways, for some say that an atavism is a return to a very distant ancestor, and reversion to a near one, while others use the two words in the opposite way. Reversion may be defined as the reappearance, through inheritance, of a character or set of characters not expressed in the immediate lineage, but in a remote ancestor. Darwin figured a Devonshire pony with a considerable number of cross-stripes on the shoulders and fore-legs; a guinea-pig may have four toes instead of three on its hind-foot; the seeds of a cultivated flower, such as a white sweet pea, may develop into individuals which are in several respects like the wild type with purplish flowers.

It is sometimes noticeable that a boy is in certain respects very like his grandfather, though we are a little apt, in catching the resemblance, to overlook the differences. This is called *skipping a generation*, but it should not be ranked as true reversion, for it is a typical occurrence in Mendelian inheritance. Similarly, the reappearance of the wild type among domesticated rabbits and pigeons which have been allowed to pair promiscuously is also a Mendelian phenomenon not to be mixed up with reversion.

True reversion, which is by no means common, is to be interpreted as due to the reactivation of an ancestral feature which has been lying for several generations unexpressed in the development, and this interpretation will not hold if there has been crossing with other breeds in which the ancestral character in question had not become latent.

TELEGONY.—Harking back, or reversion to a remote ancestor, seems to be a rare occurrence, but as to what is called **telegony** we cannot be sure that it occurs at all. Telegony is the term applied to alleged cases where an offspring resembles in some respects a sire which, though not its father, had previously paired with its mother. It is the supposed influence of a previous sire on offspring subsequently borne by a female to a different sire. The ovum or the embryo that develops with the offspring is supposed to be influenced by its mother's previous impregnation by the first sire, or by the consequences of the subsequent development.

The racehorse Blair Athol had a very characteristic white blaze on the front of his head, and it is said that mares which had once borne foals to Blair Athol subsequently produced to quite different stallions foals which exhibited the blaze. Whatever biologists say, and however negative their experiments may be, there is no doubt that many shrewd dog-breeders believe that if a thoroughbred bitch has had pups to a mongrel her value is greatly decreased, for she will not

afterwards breed true. The influence of the previous sire persists in some strange way.

In our *Heredity* (Murray, London), we have carefully considered the evidence in support of telegony, and shown its general unsatisfactoriness; but a belief in its occurrence is widespread. Let us suppose there is some basis for the belief, and ask how the phenomena, if real, could be accounted for. There is one interesting possibility. When the mammalian mother is with young, there is a very close partnership between the two. This is brought about by the placenta, which unites the unborn offspring to the wall of the womb or uterus. Through the placenta the offspring receives oxygen, dissolved nutritive stuffs, and hormones, while the mother receives from her offspring carbon dioxide, nitrogenous waste-products in solution, and, according to some authorities, certain hormones. Nothing solid passes through from either side, unless a minute parasitic organism bores its way; the exchange is between the maternal blood and the blood of the offspring. But suppose the offspring, having a father with a salient characteristic, shows that quality in its development, some representative of the quality, like a hormone, may diffuse from the offspring to the mother, and affect her constitution in some subtle way, so that when she has another offspring by a different sire, that offspring will be affected by its predecessor's peculiar quality.

MATERNAL IMPRESSIONS.—A great authority on human development has spoken of 'the mysterious wireless telegraphy of antenatal life,' and has warned us against being dogmatic in our conclusion, in regard to the influence of the mind and body of the mother on her developing child. But while we may agree that the health and spirits, the thoughts and activities of the mother may have a *general* influence for good or ill on the developing offspring, there is a danger of credulity in regard to the particular effect of particular sights and experiences. For there is a widespread belief that the body of the offspring may show marks and defects which are due to unfortunate maternal impressions while it was still within its mother. But in regard to some of these we know that the outline development of the part, say the arm, was completed before the maternal impression was received. This shows that the theory of the maternal impression is a misinterpretation, in such cases at least. Yet some breeders still believe that the colour of a calf, for instance, can be definitely influenced by keeping a good example of the colour it is desired to evoke constantly obtruded on the vision of the cow. It was this belief, probably quite erroneous, that prompted the patriarch Jacob to play his quaint trick with his master's sheep.

MENDELIAN INHERITANCE.—The laws governing the mode of inheritance, which we call **Mendelism**, were discovered in 1865 by Gregor Mendel (1822–84). Mendel was abbot of a monastery at Brünn. By means of a series of most painstaking experiments he was able to observe the nature of the inheritance of certain varieties that occur in the ordinary edible garden pea, *Pisum sativum*. The flowers of this plant are normally self-fertilized, but they can be cross-pollinated quite simply by artificial means. The results of Mendel's work were published in an obscure horticultural journal and completely forgotten until rediscovered by de Vries, Correns, and Tschermak in 1900, who independently arrived at the same conclusions. In England, Mendel's work was first appreciated by W. Bateson and R. C. Punnett.

It must be remembered that Mendel had no knowledge of chromosomes, or of those changes that the nucleus undergoes in cell-division and fertilization.

Of the various varieties which Mendel noted and with which he experimented, we may select one to show how he deduced his **first law of segregation.**

A pure-bred tall variety of pea was cross-pollinated with a pure-bred dwarf variety; the offspring were *all tall*. Mendel called tallness the **dominant** character and shortness the **recessive** character. This first filial generation is composed of hybrids in which both tall and dwarf strains are present, but the former characteristic dominates the latter. The first **filial generation** was carefully separated from the parental generation and allowed to self-pollinate, so producing a second filial generation. The second filial generation was found to be made up of talls and dwarfs in the proportion of 3 : 1. This was not the *exact* proportion; the numbers given in Mendel's data were 787 tall to 277 dwarf, or 2·81 : 1. The laws of chance must be taken into consideration, since some of the fertilizations may be unsuccessful; the greater the number of pollinations the nearer does the proportion of talls to dwarfs approximate to 3 : 1.

When the dwarf varieties of the second filial generation were allowed to self-pollinate, their offspring were all dwarfs. In this way the pure recessive strain is said to be extracted, and the dwarf varieties of the second filial generation are called **extracted recessives**, being capable of producing dwarfs only, when self-pollinated.

When the tall varieties of the second filial generation were allowed to self-pollinate, their offspring were all talls. One-third of these talls were found to be capable of producing only talls, and may be regarded as pure dominants, and two-thirds, the hybrids, produced talls and dwarfs in the proportion of 3 : 1 when allowed to self-pollinate.

These results may be summarized as follows:

Parental generation	Tall × Dwarf	
First Filial generation (*hybrid*)	Tall	(F_1)
Second Filial generation	25% Tall (*pure dominant*) 50% Tall (*hybrid*) 25% Dwarf (*pure recessive*) .	(F_2)
	Tall 25% Tall (*pure*) 50% Tall (*hybrid*) 25% Dwarf (*pure*) Dwarf .	(F_3)

Mendel, with these facts before him, considered that the parental generation contained **factors** (or **genes**) in their hereditary constitution, which were self-reproducing units. Since the two parents each contribute to the make-up of the F_1 generation, and this contains both dominant and recessive factors, the results obtained may be accounted for by supposing that each parent, as well as the hybrids, contains *two* factors making for tallness or shortness.

Further, Mendel supposed that before gamete formation the two members of each pair of factors separated or *segregated*, so that every gamete or germ-cell has one member only of each kind of unit.

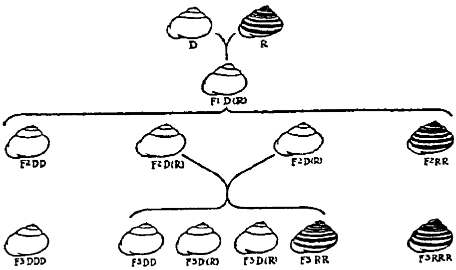

FIG. 318. MENDELIAN INHERITANCE IN WOOD-SNAIL (*Helix nemoralis*)

First row, the parents, bandless (D), *dominant*, and banded (R), *recessive*.
Second row, first filial generation, all bandless, $F^1D(R)$.
Third row, second filial generation, 25 per cent pure bandless, F^2DD, yielding bandless offspring in the next generation, F^3DDD; 25 per cent pure banded, F^2RR, yielding banded offspring in the next generation, F^3RRR; 50 per cent bandless, $F^2D(R)$, with the banded character recessive as in $F^1D(R)$. These, if inbred, yield in the F^3 generation the same ratio:

$$1\ F^3DD + 2\ F^3D(R) + 1\ F^3RR.$$

Our former table becomes more intelligible when rewritten and amplified thus:

Parents (both contain two factors)	**Tall** T.T		**Dwarf** *d.d.*
Parent germ-cells (the factors have segregated)	T T	×	*d* *d*
$\mathbf{F_1}$ **generation** (two factors again present)		T.*d*	
$\mathbf{F_1}$ **generation germ-cells**		T *d* T *d*	
$\mathbf{F_2}$ **generation**	T.T. [25% *pure dominant*]	T.*d.* [50% *hybrid*]	*d.d.* [25% *pure recessive*]

This type of inheritance is exhibited when the parents have contrasted factors, called **allelomorphs,** that do not blend when crossed. A few other allelomorphs may be given; all these were discovered by experiment. We do not yet know the reason for the dominance of one character and the recessiveness of another.

PLANTS

	DOMINANT CHARACTER	RECESSIVE CHARACTER
In Peas:		
	Tall stem.	Dwarf stem.
	Yellow cotyledons in seed.	Green cotyledons in seed.
	Round seed.	Wrinkled seed.
In Wheat:		
	Susceptibility to rust.	Immunity from rust.

ANIMALS

DOMINANT CHARACTER	RECESSIVE CHARACTER
Unbanded shell in wood-snail.	Banded shell in wood-snail.
Greyness in mouse.	Albinism in mouse.
Normal mouse.	Waltzing mouse.
Pink eye in fruit-fly.	White eye in fruit-fly.
Brown eye in man.	Blue eye in man.
Normal short hair in rabbits and guinea-pigs.	Long 'Angora' hair in rabbits and guinea-pigs.

A good illustration of Mendelian inheritance is shown in the breeding of the Andalusian fowl. This bird is of a bluish colour diluted with black, and has white lacings on the feathers. When interbred, the Andalusians do not breed true; they produce 25 per cent black and 25 per cent white with black splashes—these two forms are known as

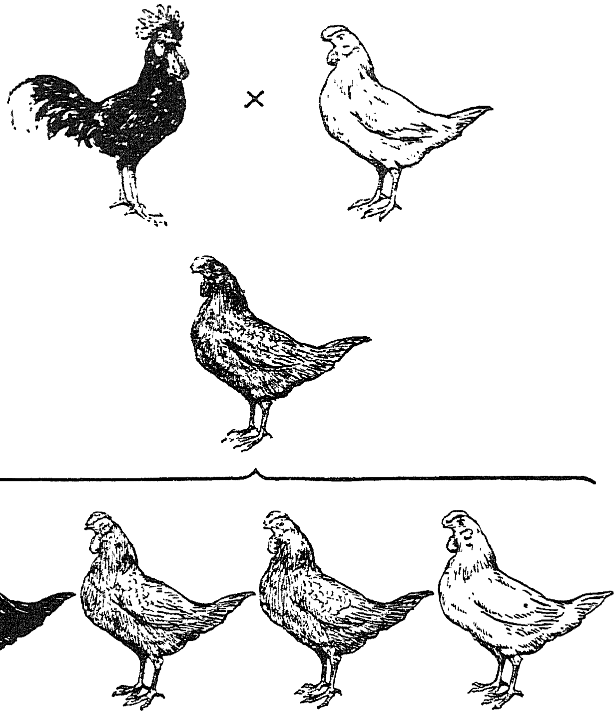

FIG. 319. MENDELIAN INHERITANCE IN ANDALUSIAN FOWLS [1]

'wasters'—and 50 per cent normal blue. The blacks when crossed *inter se*, and the white when crossed *inter se*, are found to breed true, but the blues do not. The reason for this is that the fancied blue strain is a composite hybrid and represents the expression of the 'black' and 'white' strains when they come together.

The black variety may be said to be **homozygous** in that it contains two identical factors or genes carrying blackness; in the same way the white variety is homozygous as regards the white factor. The Anda-

[1] Reproduced by permission of the publishers, Messrs. Methuen, from the author's *Modern Science*.

lusian is **heterozygous** since it is a hybrid with one factor carrying blackness and one factor carrying whiteness.

Homozygous parents	W.W. (White)		B.B. (Black)
Germ-cells	W W	×	B B
Heterozygous F_1 generation		W.B. (Blue Andalusian)	
Germ-cells		W B / W B	
F_2 generation	W.W. [25% *White* '*wasters*']	W.B. [50% *Blue Andalusians*]	B.B. [20% *Black* '*wasters*']

So far we have considered the mechanism of the inheritance of one single pair of factors only, that is, all our examples have been chosen to show **monohybridism.** When two pairs of factors are considered simultaneously we are dealing with the phenomenon of **dihybridism.**

Pisum sativum affords an example of dihybridism, since tall or short stems are inherited simultaneously with other characters which may vary. Mendel found that the seeds of this plant were either round or wrinkled, and that the factor making for roundness was the dominant one. These two pairs of allelomorphs are quite independent, and may be considered separately as if each existed alone; this was **Mendel's second law,** which may be called that of the **independent segregation** and recombination of units.

Let us suppose that the tall-roundseeded variety (both characters dominant) is crossed with the dwarf-wrinkleseeded variety (both characters recessive); then the F_1 generation will be tall-roundseeded hybrids, as the following table shows:

Parents (*pure bred*)	*Tall-roundseeded* T.T.R.R.		*Dwarf-wrinkleseeded* *d.d.w.w.*
Germ-cells	T.R.	×	*d.w.*
F_1 generation (*Tall-roundseeded hybrid*)		T.*d*.R.*w*.	

The germ-cells produced by the F_1 generation may be represented thus: T:R, T:*w*, *d*.R, *d*:*w*. We can construct a table to show

what we may expect in the F_2 generation as a result of all the possible fertilizations when the F_1 generation is allowed to self-pollinate:

Germ cells → ↓	T.R.	T.*w*.	*d*.R.	*d*.*w*.
T.R.	T.T.R.R. *Tall round*	T.T.R.*w*. *Tall round*	T.*d*.R.R. *Tall round*	T.*d*.R.*w*. *Tall round*
T.*w*.	T.T.R.*w*. *Tall round*	T.T.*w*.*w*. *Tall wrinkled*	T.*d*.R.*w*. *Tall round*	T.*d*.*w*.*w*. *Tall wrinkled*
d.R.	T.*d*.R.R. *Tall round*	T.*d*.R.*w*. *Tall round*	*d*.*d*.R.R. *dwarf round*	*d*.*d*.R.*w*. *dwarf round*
d.*w*.	T.*d*.R.*w*. *Tall round*	T.*d*.*w*.*w*. *Tall wrinkled*	*d*.*d*.R.*w*. *dwarf round*	*d*.*d*.*w*.*w*. *dwarf wrinkled*

The F_2 generation will be made up in the proportions:

9 *Tall round* : 3 *Tall wrinkled* : 3 *Dwarf round* : 1 *Dwarf wrinkled.*

and we still get the proportion 3 tall : 1 dwarf and 3 round : 1 wrinkled, which is the usual proportion of dominants to recessives obtained in the F_2 generation when considering only one pair of factors (monohybridism.)

If the factors or genes are actually carried on the chromosomes, these results are exactly what we should expect. The study of nuclear changes has shown that in the formation of germ-cells, the chromosomes lie in pairs and then separate, or segregate, as Mendel supposed the factors to do. Each pair of chromosomes is found to separate quite independently of all other pairs, so that factors carried by different pairs would thus behave as independent units.

Each chromosome apparently contains more than one gene, and the segregation of two factors is only independent when they are situated in different pairs. When the genes lie on the same chromosome they tend to 'stick together' and exhibit the phenomenon of **linkage.**

Professor T. H. Morgan and his colleagues in America have worked on this problem of linkage in reference to the small fruit-fly *Drosophila.* This small insect has provided most excellent material for their investigations, and they have actually been able to construct chromosome maps showing where the genes are situated. A discussion of this subject would, however, be too complex for us to follow further. But we should note that recent work has completely confirmed Mendel's first law of segregation, and shows that his second law holds true when the factors concerned are carried on separate pairs of chromosomes.

HEREDITARY 'NATURE' AND INDIVIDUAL 'NURTURE.'—Goldfishes kept in complete darkness for three years become blind, and the retina undergoes partial degeneration. This is an instance of a bodily change

following directly on a peculiarity of nurture, and a hundred other examples could be given. We do not know at present that the induced blindness of the goldfishes has any effect on their offspring reared from eggs developed in the light. An endeavour must be made to get more facts bearing on this question, and if the verdict should be, as the trend of research suggests, that individually acquired bodily modifications are not as such or in any representative degree transmitted to the offspring, there is the further question whether the individual experience counts for something *indirectly*, and for what?

Professor Loeb has shown that it is easy in various ways to produce in the offspring of the American minnow (*Fundulus*) a percentage of blind forms. It is enough, for instance, to expose the newly fertilized eggs for a few hours to a temperature a little above freezing-point. This indicates plainly that it need not have been the lack of light that caused the blindness of certain cave fishes and salamanders.

Shinkishi Hatai has shown that long-continued exercise (90–180 days) produces many striking changes in the white rat. The heart, liver, and kidneys increase in weight by about 20 per cent as compared with non-exercised rats similarly fed. Even the brain shows an average increase of about 4 per cent. Here again we have an example of a bodily change produced as the direct result of a peculiarity in nurture. What needs to be known, and will eventually be known, is whether this sort of individual experience counts for anything racially. There can be no return to the old belief in the transmission of any and every individually acquired character, but it is probable that we shall discover by and by that individual experiences count for something in evolution.

Species and Specificity

It is characteristic of living creatures that they can be grouped in kinds or species consisting of similar individuals. Every one recognizes a lion at a glance, and sees that all the lions are more or less like one another, apart from differences of age and sex. All the lions are referred to as being of the same kind or species, *Felis leo*; and, similarly, all the tigers as another kind or species, *Felis tigris*. But these two species taken together form the larger company of Cats, the **genus** *Felis*, which also includes leopards, lynxes, jaguars, wild cats, and other species. In some cases, however, the genus has only one species, e.g. the okapi or the narwhal.

A **species** is a collective name for all individuals sharing the same detailed characters, which are more or less constant from generation to generation, and are more significant than the differences distinguishing the members of a family (using this word to mean offspring

of the same parents); moreover, the members of a species are usually fertile with one another, and are not usually fertile with the members of related species.

To this definition we must add a few notes:

(1) A species is not an abstraction, but a group of similar individuals. Its members may be found all over the world, or, when the species is dwindling away, as the American passenger pigeon did, the whole species may be contained in one garden or aviary. But whether it be large or small, the species consists of real individuals.

(2) The similar detailed characters, on the strength of which the naturalist invents a name for the species, such as *Passer domesticus* for all the house-sparrows, must not be trivial; and here it is that differences of opinion arise. For some would say that the common possession of such-and-such characteristics is worthy of a special name, while other naturalists regard these chosen characteristics as trivial. Thus arise disputes between the 'lumpers,' who try to reduce the number of separately named species, and the 'splitters,' who are all for recognizing more and more of these 'groups of similars.' To check over-multiplication of species we should ask whether the characteristics chosen as the basis of the species are fairly constant from generation to generation; are in the strict sense inborn, and not imprinted by the environment; and are greater than those that frequently occur among the offspring of a pair.

(3) Many species are at present in a state of flux, so that one must not press too hard the criterion of a 'good species' that its characters persist much the same from generation to generation. Yet this hereditary persistence is on the whole true, and although the outcrop of intermediate **variations** often serves to link one species to its nearest neighbour, the larger fact is **discontinuity.** This is also emphasized by the fact that most species are not readily fertile with their neighbour species.

(4) Within a species there are often minor groups of similar individuals, and these are called **sub-species.** Their features are not so far apart from one another or from the main species as those of a good species are from its neighbour's. Different sub-species are often found in different geographical conditions, and inquiry must be made to try to make sure that the differenccs between the sub-species and the typical species are not **modifications,** hammered on to each successive generation by peculiarities in nurture. More experiments are needed.

In what is called the **binomial nomenclature,** established by Linnaeus, a species gets two names, e.g. *Felis leo,* the first name being generic. But when a species includes clearly different sub-species it is convenient to use *three* names. Thus the mountain hare or variable

hare of Scotland, which turns white in winter, is usefully called *Lepus timidus scoticus*, for it has peculiarities which warrant its separation by name from the Alpine variable hare, *Lepus timidus alpinus*. Yet the Scottish sub-species is nearer to the Alpine one than either is to the common brown hare, *Lepus europaeus*, which is a clearly distinct species.

(5) Inquirers often ask the reasonable question: How does a **variety** differ from a species? We may give part of the answer in a few words. A variety is a group of similar variants that have arisen as variations within a species. It is a possible new species, a species in the making. But it has not the stability of a species; it is apt not to breed true; its peculiarities are not so important as those of a good species; the variants pair readily among themselves and with the originative stock. The difference between a species and a variety is one of degree. As examples of varieties we may select, from among thousands, the white variety of the red flowering currant, the greater celandine with cut-up or laciniate leaves, an Angora cat, a lop-eared rabbit, a hornless calf. When a variety arises under man's control, it is called a breed, or, when it becomes more stable, a race, like the races of domesticated pigeons, poultry, wheat, and potatoes.

(6) Perhaps the most difficult thing to understand in regard to the origin of species, apart from the causes of the originative variations or mutations, is the usual sterility with adjacent species.

Keeping **specificity** for the uniqueness of a species or kind, we may use the term **individuality** to mean that every individual organism is unique, with peculiarities of its own. The term is often used to mean the personality or the peculiar features of an organism, as when we ascribe to a man or to a horse 'a strong individuality,' but we are using the word here to mean the uniqueness of each individual, a very good instance in man's case being the pattern of the finger-prints, which are different for each one of us, except sometimes in the case of identical twins.

A very striking case of this individuality has been worked out by Mr. Charles Todd, F.R.S. In the case of the domestic fowl he has found it possible, by means of simple immunity reactions, to differentiate the red blood corpuscles of any particular fowl from those of any other individual of the same species, except in certain cases where there is close blood-relationship. It is rather an achievement, we think, to be able to prove that the red corpuscles of any individual fowl possess individual characteristics distinguishing them from those of any other individual not a close blood-relation; and it looks as if this individuality applied to most of the other cells of the body. Moreover, a comparison of the red corpuscles of chicks with those of possible parents allows in some cases the identification of at least one of the parents. Thus, if the

methods develop, there may be a possibility of proving paternity by an examination of the red blood corpuscles. Brother chicks can be distinguished in similar ways; in fact no two chicks have exactly similar corpuscles. This is a foundation-stone in the establishment of a doctrine of organic individuality.

Individuality may affect everything, from fine details of cell-structure upwards; the cells lining the windpipe of a dog are demonstrably different from those in a similar position in a rabbit, and a tiger's skull is easily distinguished from a lion's. Among Alcyonarian corals, of which we have made a hobby, the details of the spicules that form an armature around the polyps are often quite diagnostic; and many a field-naturalist can identify a bird from a single feather that it drops. A species should be in many ways *itself and no other*.

Apart from structure, it is a commonplace, but an important one, that this individuality often expresses itself in unimportant details of habit. A good instance is given by Dr. Charles Hose in his fascinating *Fifty Years of Research and Romance* (1928). Dealing with his experiences in Borneo, he contrasts the three ways in which three related animals will deal with a bowl of something drinkable placed before them on the ground. The orang-outan generally bends down and drinks out of the bowl without handling it. The gibbon, also an anthropoid ape, dips one hand into the bowl, and then, throwing its head back, sucks the moisture off the hair on the back of the hand, repeating the process time after time till its thirst is slaked. But the ordinary macaque monkey, though farthest away from human kind, lifts the bowl up, if not too heavy, with both hands, and drinks out of it much as a man would. Of course thousands of instances of this specificity of behaviour might be given; but it is an eloquent fact to be kept always in mind.

What are Genes?

In the section on Mendelism we have had occasion to refer to 'genes.' Let us inquire now a little more fully into their nature. An inheritance is carried, in some way that we cannot definitely picture, inside a germ-cell; and it is carried, more or less equally, by the egg-cells, produced by the female, and the sperm-cells, produced by the male. When an egg-cell is one-hundredth of an inch in diameter, it is not counted as very small; and a sperm-cell may be only one-hundred-thousandth the size of the egg-cell. Yet, as regards many features, it is certain that the egg-cell and the sperm-cell contribute equally to the inheritance, which is reunified in the fertilized egg-cell and expressed in the developing offspring. But as the part of the sperm-cell or spermatozoön that enters the egg-cell or ovum

is almost entirely made up of nuclear or chromatin material, there being very little cell-substance or cytoplasm, it follows that as regards many features the vehicle of the inheritance is the nucleus of the germ-cell. It is too soon to assert dogmatically that the whole of the inheritance is carried by the nucleus, for a little cytoplasm may go a long way, and it may be that the cytoplasm, which is often as relatively large in the ovum as it is small in the spermatozoön, may carry some of the more ancient hereditary characters. In any case the egg-cell may often count for more in the future offspring than does the fertilizing sperm-cell, for the egg-cell has initial building material in its extra-nuclear cytoplasm. It will be understood that when an egg is really large, like the egg of a salmon or of a hen, this means that there is a considerable legacy of nutritive material or yolk. The amount of genuine living matter—the formative material, whether nuclear only or nuclear and cytoplasmic together—is never large. It must also be understood that the nourishment of the developing offspring within the mother before birth is not to be counted in as part of the inheritance, for though it is characteristic of mammals, it is not illustrated in the majority of animals.

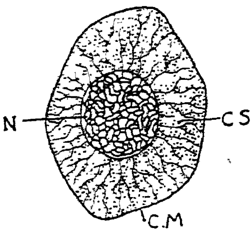

FIG. 320

STRUCTURE OF A CELL

N, nucleus with chromatin; CS, cell-substance or cytoplasm; CM, cell-membrane.

It may be stated, then, as a biological certainty, that many at least of the hereditary characters of our sheep and cattle, of our turnips and cereals, are carried in the germ-cells by the chromatin material of the nucleus. This **chromatin**, so called because it stains readily and can thus be more readily studied under the microscope, tends to be grouped in distinct bodies or **chromosomes**, definite in shape in different types and definite also in number. The smallest number of chromosomes in a cell is two, as is seen in the threadworm (*Ascaris*) of the horse; one of the large numbers is forty-eight, which occurs in man. No great importance can be attached to the particular number of chromosomes, thus man's number occurs also in one of the snails and in one of the plantains; the point is that the number, whatever it may be, occurs constantly throughout the cells of the body, except that the ripe ova and the ripe spermatozoa have half the normal number. When the egg-cell is fertilized by the sperm-cell, the normal number will be restored.

Another interesting point about the number of chromosomes has been demonstrated in a number of cases, both among plants and among animals, viz. that related species sometimes show an arithmetical series of chromosome numbers. Thus some species of rose have

seven chromosomes, others fourteen, others twenty-eight, and so on. It is known that a sudden novelty—whether we call it a freak or a sport or a mutation or a discontinuous variation, matters little—may be associated with a doubling of the number of the chromosomes in the germ-cells.

Another point of interest in regard to the number of chromosomes in a particular kind of living creature—whether horse or threadworm, turnip or bean-plant—is that it may sometimes throw light on the failure of crossing or hybridizing. When the chromosome numbers of two different species are quite different, it is not likely that there will be a successful cross, and it is still more unlikely that the cross, if it comes off, will be fertile. But here we must draw back from deep waters.

Yet another point, which touches us all. It often happens that the cells in the male's body have one chromosome fewer than those in the female's body. Thus man's number is forty-seven, but woman's number is forty-eight; and thus we men start handicapped! Now in those mammalian types that have been carefully studied there seem to be two kinds of ripe spermatozoa, which occur in equal numbers, one half with, and one half without, a special 'sex-chromosome.' In the female, however, the ripe egg-cells are all alike, each with a 'sex-chromosome' as well as half the usual number of ordinary chromosomes. When an egg-cell is fertilized by a spermatozoön carrying a special 'sex-chromosome' along with half the usual number of ordinary chromosomes, the result is likely to be a girl (with forty-eight chromosomes in all). When an egg-cell is fertilized by a spermatozoön without a special 'sex-chromosome,' the result is likely to be a boy (with forty-seven chromosomes in all). As this applies to mammals in general, it is plain that what appears at first sight very technical is really of profound practical importance. The theory is important, as yet, in enabling us to understand more clearly what occurs, but in days to come it will probably help man to control as well. But let us return to the microscopic vehicles of the hereditary characters.

When a cell has been fixed and stained to facilitate microscopic examination, the chromosomes sometimes appear almost too distinctly, like very solid rodlets or V's or spheres or threads; but in the living cell they are very fluid and somewhat vague in outline. One of our wits has spoken of a sausage as 'a little bag of mystery,' and that is what a chromosome is—a very intricate colloidal sausage surrounded by a delicate film. Under high magnification it is sometimes seen to be divided into a number of regions, presenting in the living state a somewhat irregular contour. In these parts of the chromosome and probably in longitudinal order, like a row of beads, are the 'genes'—which are in some ways the most important things in the world.

For a gene is a differentiation—probably a little particle or blob—which is the hereditary initiative or representative of a hereditary unit character. A 'gene' or 'factor' is the germinal counterpart of a normally non-blending and non-splitting characteristic or feature, but it must be understood that several genes may go to the development of one feature, such as the colour of the hair; and that one gene may influence the development of several distinct features in the organism.

A question often asked is whether one can see a gene, and it is possible that a visible minute nodosity on a chromosome is occasionally a single gene. In most cases the little swellings are more probably linkages of genes. In indirect ways, however, which cannot be very briefly described, it is more or less certain that the genes lie in linear order on the thread of the chromosome; that groups of them may pass from one chromosome into another which crosses over it; that they can move as units; and that they are capable of some change in molecular structure. Dr. C. B. Bridges has pictured a gene as the central core of a minute body containing sap enclosed in a film. He suggests that though we may not be able to see the genes themselves, we can see the tiny houses in which they live. The most certain fact in regard to genes is that they are the most important little bodies in the world, and therefore very much within the purview of the biologist.

CHAPTER VIII

EVOLUTION

What is Evolution?—Organic Evolution—Historical Survey—Evidences of Evolution: (1) Lineage series in palaeontology; (2) Geographical distribution of races and species; (3) Comparative anatomy; (4) Life-histories or embryology—Modes of Evolution; Lamarckism and Darwinism—Conclusion: Evolution still going on; Great steps in Evolution; The pageant of Evolution.

WHAT IS EVOLUTION?—Definitions should come last, not first; but we may say that Evolution is a natural process of 'becoming.' It is plain that there are several different kinds. Thus there is *cosmic* evolution, which may be illustrated, for instance, by the establishment of our solar system out of a nebular mass. There is *chemical* evolution, which may be illustrated, for instance, by the production of radium out of uranium. There is *social* evolution, which may be seen in the rise of complicated societies and their institutions. There is *organic* evolution, as in the emergence of Birds from an extinct reptilian ancestry.

These are very different kinds of evolution, but they have this in common, that there appears, by gradual natural change, something definitely new. We mean by 'natural,' in this case, that the factors bringing about the changes are such as may be scientifically verified as operative in the material under discussion. The present is the child of the past and the parent of the future—that is the idea of evolution. 'Everything,' said Bagehot, 'is an antiquity with a long history behind it'—that is the idea of evolution.

ORGANIC EVOLUTION.—There is no possible doubt as to changes that have come in the plants and animals that are and have been the tenants of our earth. Thus the rock records show that for a long time after living organisms began to people the earth, there were only backboneless animals; after millions of years there was an emergence of Fishes, but there is no trace among them of fossils of any higher backboned type. Then, in the late Devonian, the pioneer Amphibians, ancestors of our frogs and newts, made an appearance, and we know them first by their footprints. Ages passed and Reptiles had their Golden Age; from extinct stocks of Reptiles there emerged Birds and Mammals; until at last, perhaps a million years ago, there was a beginning of 'tentative men.' This ascent of life shows a slow changing of races—an appearing and then a disappearing—which is

called Organic Evolution. There is no theory about it; there is, on a grand scale, an actual historical sequence, and our descriptive account of this is like our narrative of what has happened in the ascent of man. And just as we often use the word 'history' for the actual process of man's ascent, as well as for the narrative, so it is with our use of the term Organic Evolution.

HISTORICAL SURVEY.—To the layman the theory of Evolution is always associated with the name of Charles Darwin. That this should be so is not surprising, for Darwin was the great advocate for Evolution and has been the dominating influence in this sphere of thought on all those who have followed after. He convinced his fellow-biologists of the truth of Evolution and was the first to suggest a means whereby it has been brought about which should be acceptable to the vast majority of scientists. Darwin, however, did not originate the idea of Evolution; for this we must go to the Greeks.

Aristotle (384–322 B.C.), the founder of Natural History by accurate and careful observation, believed in a complete gradation in Nature. He saw progressive stages of development beginning with the lowest stage, the inorganic world, passing up through plants and animals, and finally culminating in Man. In speculating on a *raison d'être*, his philosophy was anthropocentric, for 'plants are evidently for the sake of animals and animals for the sake of Man; thus Nature, which does nothing in vain, has done all things for the sake of Man.' With the fall of the Greeks a period of thought ended, though many of our modern theories on evolution had been anticipated. We do not find any of Aristotle's ideas improved upon until the eighteenth century. In 1756 there began to practise in Lichfield a doctor of great personality who was in many ways similar to his fellow-townsman Dr. Johnson. This was Dr. Erasmus Darwin, the grandfather of Charles Darwin. After publishing several of his speculations in biology in the form of verse, during the course of his medical practice, he presented the learned world, in 1794, with his *Zoönomia or Laws of Organic Life*. This was an attempt to classify animal life and then, by comparison of the various forms, to arrive at some conclusions with regard to the theory of diseases. In this work he affirms his belief in the origin of all life from 'some kind of living filament,' and in dealing with the causes which have produced different kinds of animals he says: 'All animals undergo transformations which are in part produced by their own exertions, and in response to pleasures and pains, and many of these acquired forms or propensities are transmitted to their posterity.' Here is stated for the first time the belief in the inheritance of acquired characters as a means of producing evolutionary changes. Though Erasmus Darwin's work marks the dawn of modern evolutionary ideas, he is overshadowed by

Lamarck, who independently arrived at the same conclusion a few years later.

Lamarck (1744–1829) occupied the chair of Zoology in the Jardin des Plantes (Paris) and early distinguished himself as an accurate observer, descriptive writer, and systematist. The Lamarckian doctrine of the causes of Evolution, wherein lies his claim to fame, is stated in his *Philosophie Zoologique*, published in 1809. He summarizes his own theory thus: 'Great changes in environment bring about changes in the habits of animals. Changes in their wants necessarily bring about parallel changes in their habits. If new wants become constant or very lasting, they form new habits, the new habits involve the use of new parts, or a disuse of old parts, which results finally in the production of new organs and the modification of old ones.' And again: 'All that has been acquired, imprinted, or changed in the organization of the individual during the course of its life is preserved by generation and transmitted to the new individuals that descend from the individual so modified.'

He was unfortunate in his choice of examples and inconsistent with his own theory when he suggested that the organ of hearing had been developed everywhere by the *direct* action of the vibrations of sound. Through lack of evidence his theory was dismissed by his contemporaries as the wildest speculation. His old age was saddened by poverty, blindness, and the strong criticisms of his work on all sides.

The chief interest of professional biologists at this time lay in morphology and classification, under the stimulus of the great Swedish systematist Linnaeus; so that the theories of Erasmus Darwin and Lamarck soon sank into oblivion, and interest was not reawakened until the publication of Charles Darwin's *Origin of Species* fifty years later. Charles Darwin (1809–82) was the son of a doctor practising in Shrewsbury. Charles was sent to study medicine at Edinburgh, but stayed there only two years as he showed no aptitude for the subject. He then went to Cambridge with the intention of taking Holy Orders later on.

His time at Cambridge was uneventful except in so far as he impressed Henslow as an amateur naturalist and a suitable person to accompany, as honorary naturalist, a scientific expedition which was then (1831) setting out in H.M.S. *Beagle* to South America. Darwin was at this time twenty-two years old; he spent five years on the expedition. During this period he became a biologist and geologist through his own observations and effort, and accumulated abundant first-hand material for the formulation of his great theory of natural selection. He returned home a convinced evolutionist and began to ponder the great question: How did the numerous species or kinds of living things, plants and animals, that are or have been upon the

earth, come to exist? Darwin, being naturally reticent, might never have published his conclusions if it had not been for the persuasions of his friends Hooker and Lyell. By a curious coincidence his friend Alfred Russel Wallace, traveller and biologist, had arrived independently at the same conclusions whilst in the Malay Archipelago. Wallace sent his manuscript to Darwin and the theory of the two friends was made public in the *Journal of the Linnean Society* in 1858. A year later Darwin published the *Origin of Species*, the substance of which will be discussed later.

It would be incomplete to conclude this brief historical survey without mention of Thomas Henry Huxley, a contemporary of Charles Darwin, who gave such strenuous support to the theory of Evolution. Huxley, a brilliant writer and speaker, was able to do what Darwin could never have done, in joining battle with the opposition whenever the occasion arose. A convinced Darwinist, he devoted his life to the promulgation of what he considered to be the truth.

EVIDENCES OF EVOLUTION.—There is no competent biologist to-day, however sceptical or inquiring he may be, who has any doubt as to the *fact* of Organic Evolution, but no one would assert that it can be demonstrated as one might demonstrate the Law of Gravitation, or even the Conservation of Matter and Energy, still less the development of a chick out of a drop of living matter on the top of the yolk of an egg. But how, one may ask, can a conclusion be accepted without hesitation if it is not rigorously demonstrable? The answer is that the evolution-idea is a master-key that opens all locks into which we can fit it, and that we do not know of a single fact that can be said to be in any way contradictory of it. Like Wisdom, the evolution-idea is justified of its children.

In regard to the factors or causes of the evolutionary changes there is, inevitably, great difference of opinion among biologists, for the inquiry is as young as it is difficult. It is, however, unfair to use this admission of uncertainty of *method* as if it implied any hesitation to believe in the *fact* of an agelong evolutionary process in which, in many cases at least, the highly specialized and very perfect types are shown, by the rock records, to be preceded by a gradual succession of less finished stages.

We may conveniently group our 'evidences' under several headings, as follows: (1) Lineage Series in Palaeontology; (2) Geographical Distribution of Races and Species; (3) Comparative Anatomy; (4) Life-histories or Embryology.

(1) **Lineage Series in Palaeontology.** As to how life arose on the world we know nothing, but during the course of ages there has been a gradual emergence of finer and nobler forms of life. Among backboned or Vertebrate animals the first were Fishes; they led on to

Amphibians; these were succeeded by Reptiles; and later on there arose Birds and Mammals. Since the Mammals include Man we put this group at the top of the evolutionary tree, though the Birds were actually the last to appear in order of time. Detailed pedigrees are disclosed in the rocks, often with marvellous perfection, as in the case of horses and elephants, camels and crocodiles. The modern *Equidae* or horses originated from five-toed, primitive mammals which existed in Eocene times. The place of evolution of this group was in North America and Europe, which were at one time connected by a land bridge across the Bering Strait. In recent times the group became confined to Europe and was re-introduced into America by man's agency. The main trend of evolution in the *Equidae* has been towards a form modified for cursorial habits; this has meant that the soles of the feet have been raised from the ground, the middle digit in each foot becoming more and more important as the other toes degenerated into mere vestiges. The entire weight of the modern horse is supported on the tips of four digits.

Many Invertebrate animals, such as worms, have left little or no record of their evolutionary progress, since their soft bodies, being without shell or bone, were unable to form imprints in the rocks. In some cases, however, such as freshwater snails and marine cuttle-fishes, there is an almost perfect succession of fossils, forming a chain, with link 10 very different from link 1, yet as little different from 9 as 2 from 1.

Huxley considered that palaeontology, or the study of fossil records, constituted the only really sound basis for theories of evolution: yet the foundations of the subject were laid by Baron Cuvier, a convinced 'special creationist.' Cuvier held important scientific posts under Republican, Napoleonic, and Restoration régimes. He showed by careful examination that there had once flourished in Paris fossil Vertebrates totally different from the living forms of his own times. He also found that different groups of Vertebrates were lying at different levels in the limestone. His conclusion was that there had been a succession of different groups, each destroyed in turn by a geological catastrophe and replaced by new ones at the hand of the Creator. This reminds us of Joseph Priestley, a convinced phlogistian to the end of his life, yet whose discovery of oxygen was the means of finally overthrowing the phlogiston theory of combustion.

(2) **Geographical Distribution of Races and Species.** The geographical evidences are endless. If the present state of affairs is not the outcome of a natural process of evolution, why should oceanic islands be restricted in their fauna to those animals which may indubitably have arrived from over the sea, borne by currents, by winds, or on the feet of birds? Thus the fact that there are no amphibians on oceanic

islands becomes easily explicable when we know that very few amphibians can endure salt water.

The inhospitable Galapagos Islands are said to be the tops of extinct and submerged volcanoes, belonging to an ancient peninsula that became first an island and then an archipelago. They have a peculiar fauna, including the famous giant tortoises. There are nine different kinds of giant tortoise on nine different islands, and those that are furthest apart are most unlike. There are five further different kinds in different corners of the largest island, which is called Albemarle. If we keep to the first fact, what can it mean except that isolated groups of one ancient stock have varied slightly on the various islands, and that the isolation prevented any pooling or blending of the new departures? For these tortoises are poor swimmers. In the case of Albemarle Island, the isolation is probably topographical and due to barriers formed by the rugged volcanic surface. When Darwin visited these islands on the *Beagle* voyage, he was greatly struck by the facts just related, and he tells us that he felt himself 'brought near to the very act of creation.'

Similarly, the distribution of present-day marsupials offers more indirect evidence. The marsupials represent adaptive radiation of a primitive mammalian stock which arose in the northern hemisphere and migrated southwards. At one time they were fairly well distributed over Europe and North America, whence they spread into Australia and South America. The Antarctic land bridge was cut off before the more capable placental mammals were evolved and began to migrate southwards. In this way the marsupials have escaped competition in Australia and have undergone adaptive radiation, occupying most of the 'niches' that are occupied by placental mammals in other parts of the world. A few species, such as the opossums, have managed to survive in America, but no marsupial is found to-day in Europe, Asia, or Africa.

(3) **Comparative Anatomy.** It is interesting to compare a number of fore-limbs—our own arm, a bat's wing, a whale's flipper, a horse's fore-leg, a bird's wing, a turtle's paddle, a frog's arm, and a giant giraffe's at the other extreme. They are very different, yet when we scrutinize them we find the same fundamental bones and muscles, blood-vessels and nerves. 'How inexplicable,' Darwin said, 'is the similar pattern of the hand of man, the foot of a dog, the wing of a bat, the flipper of a seal, on the doctrine of independent acts of creation! How simply explained on the principle of the natural selection of successive slight variations in the diverging descendants from a single progenitor.'

This similarity of structure is to be found in all closely related animals; and, moreover, when we investigate with the biochemist the

chemical nature of living material and the products of metabolism we find a remarkable similarity between all animals. As J. B. S. Haldane says in his *Causes of Evolution*: 'There may be some reason in the chemical nature of things why all living creatures must contain glucose. But there appears to be no reason, other than common ancestry, why they shall all contain dextro-rotatory glucose, and none of them its mirror image.'

Another anatomical argument is to be found in the frequent occurrence of vestigial structures in animals and in ourselves. Useless dwindled relics of the hind-limbs of whales are found buried below the surface. Behind the eye of the skate—a familiar flat-fish—there is a large hole called the 'spiracle.' It serves for the incoming of 'breathing water,' which washes the gills and passes out by the five pairs of gill-clefts on the under-surface. But if we peer into the very useful breathing-hole or spiracle, we see a minute comb-like structure, which is the dwindling, useless, relic of a gill. The cleft or spiracle is indispensable to the skate, but the relic or vestigial gill inside the spiracle is of no use at all. Yet it tells us unmistakably that a spiracle was evolved from a gill-bearing gill-cleft.

We live in what has sometimes been called the 'Age of Insects,' for there are well over a quarter of a million different kinds of these animals. Now, it is significant that, by carefully comparing the anatomy of one form with another, insects can be classified in an orderly way, and that in many cases one can make plausible 'genealogical trees.' Often one species, with its varieties, seems to fade into another. In many parts of the animal kingdom there are types that link great classes together. Thus the old-fashioned *Peripatus* type, a little creature somewhat like a permanent caterpillar, possesses both Annelid characters and Arthropod characters. It is to some extent a connecting-link. The oldest known bird, a fossil beautifully preserved in lithographic stone of Jurassic Age, has numerous reptilian features, such as teeth in both jaws, a long lizard-like tail; a half-made wing, and abdominal ribs. Yet it was a genuine member of the phylum *Aves*—a true bird.

(4) **Life-histories or Embryology.** Very striking are the embryological facts which indicate that the individual development is, so to speak, a very much condensed recapitulation of the racial evolution. An embryo-bird is for some days almost indistinguishable from an embryo-reptile; they progress along the same high road together; but soon there comes a parting of the ways and each goes off on its own path. The gill-slits that are associated in fishes and tadpoles with the passing-out of the water used in breathing, are persistent in all the embryos of reptiles, birds, and mammals, though in these higher backboned animals they have nothing to do with respiration.

All of them are merely transient passages, except the first one, which becomes what is called the 'Eustachian tube,' leading from the ear to the back of the mouth. They are straws which show how the evolutionary wind has blown. In a great many ways it is true that the individual animal climbs its own genealogical tree; but we must be careful not to think that an embryo-mammal is at an early stage of its development like a small fish, as some writers have carelessly implied. Each living creature is from the very first stage of its development itself and no other; and though the tadpole of a frog has for some weeks certain features like those of fishes, especially larval mudfishes, it is an Amphibian from first to last. It is necessary to be careful in speaking of the way in which individual development recapitulates racial history, but there is no doubt that the hand of the past is upon the present.

From these few evidences the nature of the evolutionist's argument will be plain. It is a *cumulative* argument. All the lines of facts meet in the same conclusion—the present is the child of the past. There is no conflicting evidence; every new discovery points in the same direction. On many different sides we find striking facts which are luminous when we see them in the light of the evolution idea. But without that light they are incomprehensible.

MODES OF EVOLUTION.—We have already referred to Lamarck's contribution to the study of Evolution. His theory as to how the changes in the form of animals and plants have been brought about bears the name Lamarckism and may be stated as follows: 'Modifications arise in animals during their lifetime as a result of stimuli which they receive from their surroundings.' Lamarck was careful to note, however, that the environment can effect no *direct* changes whatever upon the organization of animals.

Also, through disuse, certain organs in the animal's body may dwindle. These modifications, according to Lamarck, are inherited to a certain extent by succeeding generations, and the accumulated modifications in time produce a new kind of animal. Thus, on the Lamarckian theory, *Proteus*, the blind salamander of the Austrian caves, through living continuously in the dark has lost the power of sight. The accumulated legacy of poorer and poorer eyes has resulted in an inheritance of permanently degenerate eyes hidden beneath an opaque skin. Professor MacBride summarizes Lamarckism when he says: 'Habit is response to environment, and inherited structure is nothing but the crystallization of habits of past generations.'

The crux of the matter is whether acquired characters can be inherited. The majority of biologists regard Lamarck's theory as still unproved, in spite of the claims of a few workers to the contrary.

Darwin's theory of natural selection as a means of evolution was

set out in the *Origin of Species*, published in 1859. That this book is still read and discussed,[1] three-quarters of a century after publication, proves its importance, since the majority of theoretical scientific works are soon out of date. Owing to the author's thoroughness and sound judgment, the book is still vital, though the theories set forth should be supplemented by books dealing with more recent work on the subject of heredity.

Darwinism may be stated briefly thus: No two animals—or plants—are exactly alike. There are always slight differences or variations in size, colour, shape, and intelligence. Owing to the rate at which all living forms tend to increase, there is a continual **struggle for existence** in the competition for food and shelter. The variations in form that have proved advantageous will increase their possessor's chances of survival. In this way there is a **natural selection** where the 'weakest go to the wall' and the 'fittest' survive, ultimately to reproduce and transmit their heritable variations to their offspring.

The less fitted may also breed before elimination, but their reproductive period would be shortened, so that the numbers of the offspring would be reduced.

'Let us take the case of a wolf,' says Darwin in Chapter IV of the *Origin of Species*, 'which preys on various animals, securing some by craft, some by strength, and some by fleetness; and let us suppose that the fleetest prey, a deer for instance, had from any change in the country increased in numbers, or that other prey had decreased in numbers, during that season of the year when the wolf was hardest pressed for food. Under such circumstances the swiftest and slimmest wolves would have the best chance of surviving and so be preserved or selected—provided always that they retained strength to master their prey at this or some other period of the year, when they were compelled to prey on other animals.'

It should be noted that this theory depends on three main factors: **variation, a struggle for existence,** and **inheritance of variations.**

There is no doubt about the occurrence of small variations which all living forms inherit; these must not be confused with variations which animals may acquire during their lifetime as a result of the interaction with their environment. There are also large variations which crop up unexpectedly and spontaneously; these are called **mutations** (p. 1012) and are always heritable. In illustration of mutations we may quote T. H. Huxley, who said in *Darwiniana*: 'It appears that one Seth Wright, the proprietor of a farm on the banks of Charles River, in Massachusetts, possessed a flock of fifteen ewes and a ram of the ordinary kind. In the year 1791, one of the ewes presented her owner with a male lamb, differing, for no assignable

[1] And, in the first edition, much sought after by bibliophiles!

reason, from its parents by a proportionally long body and short bandy legs, whence it was unable to emulate its relatives in those sportive leaps over the neighbours' fences, in which they were in the habit of indulging, much to the good farmer's vexation.' This mutation was heritable and its possessor became the progenitor of a new breed.

Darwin said: 'Our ignorance of the laws of variation is profound,' and we still do not know the causes of mutations.

Of the struggle for existence there is no doubt. The potential fertility of animals and plants is enormous. If an annual plant produced only two seeds each year and their seedlings each produced two seeds next year, and so on, in twenty years there would be a million plants. Owing to the small chance of survival, this appalling increase of a single species rarely takes place. Similarly the cod, to take one instance from the animal kingdom, lays some 6,000,000 eggs annually. In spite of these large numbers, the stock remains fairly constant, so that on the average only two eggs actually attain maturity. When, for some reason, a new plant is introduced into fresh territory, where there is little competition and its fertility is unrestrained, the numbers rapidly increase until every available space is seeded.

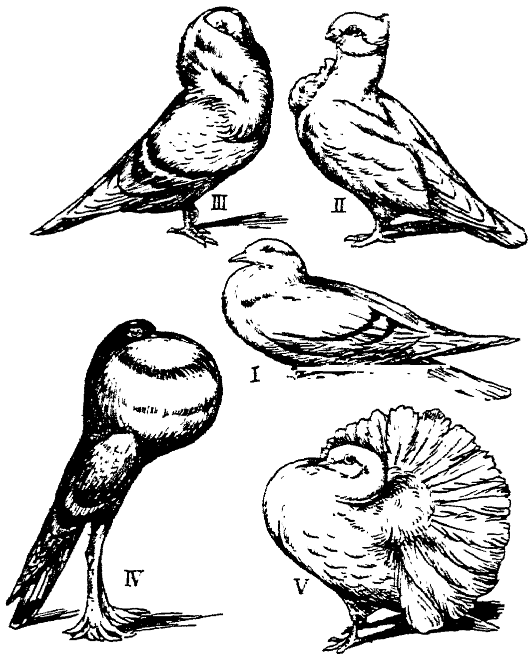

FIG. 321. VARIOUS BREEDS OF PIGEONS
I, the ancestral rock-dove (*Columba livia*); II, turbit; III, jacobin; IV, pouter; V, fantail.

Finally we must consider the nature of the inheritance of those variations which have enabled an animal or plant the better able to compete in the struggle for existence. It was considered at one time that in mating with the normal strain, a strong variation would be subjected to a swamping effect as a result of intercrossing and the offspring would therefore exhibit the variation only to a minor degree.

After several succeeding generations the variation would be very slight and cease to be of any importance. We now know, however, as a result of the work of Mendel (see MENDELISM), that if such a variation be a 'dominant' one it will be inherited unchanged by the next generation. The normal or 'recessive' strain of the other parent will reappear unchanged in the second successive generation. Thus, although only 25 per cent of the second generation will exhibit the 'recessive' strain, both varieties survive without any swamping taking place and both will have their effect on the chances of survival of future generations.

Man as breeder or domesticator has performed what Darwin supposed was continually taking place in Wild Nature. The wild rock-dove (*Columba livia*), which still thrives on some of the cliffs round the British coasts and in the Mediterranean region, has been the origin of many races of domestic pigeon. The bird was partly tamed; it bred in captivity; variations or new departures cropped up, as so often happens; man isolated those that pleased him and bred, *inter se*, similar variants. Gradually he established true-breeding varieties or races, such as homers, carriers, tumblers, fantails, and so on. A variety differs from a species only in degree; it is often a species in the making. It is less stable than most species are, and it usually breeds with the varieties nearest to it more readily than the members of a species breed with those of the species nearest to them, e.g. dog or wolf.

In our present stage of knowledge we cannot say that either Darwin's or Lamarck's theory has been completely and convincingly proved. It should be noted that Darwin, towards the end of his life, was more tolerant of Lamarckism; he was probably not far from the truth when he wrote, at the conclusion of his Introduction to the *Origin of Species*:

'I am convinced that natural selection has been the most important, but not the exclusive, means of modification.'

Evolution still Going On

It is difficult to demonstrate that we are the descendants of prehistoric Europeans, and it is difficult to demonstrate that Birds evolved from Reptiles, but both statements are correct. It will not do to say that the origin of Birds is a scientifically insoluble problem, for that is prematurely dogmatic; and it will not do to say: 'Enough for me that the new races arose by the will of God,' for the evolutionist may believe that just as earnestly as the special creationist.

Yet we cannot object to our critics who say: If evolution is a name for the gradual natural processes by which a new race emerged from an older one, then there should be some hints of this going on to-day.

In point of fact, the world is crowded with these hints. It is necessary, however, to remember how very slow the processes of organic evolution usually are. Man cannot expect to see much in three score years and ten. And yet, how blind we are if dog-shows and poultry-shows, flower-shows and fruit-shows do not show us *evolution going on*!

It has not taken very long for all the breeds of domestic pigeon to arise under man's shield from the wild rock-dove, still common enough on sea cliffs in the west of Scotland. It has not taken very long for all the breeds of poultry to arise from the Indian jungle-fowl.

Geologists say that if we could make a great film showing in proportion the successive geological periods, with the appropriate plants and animals and scenery for each successive age, and could arrange to unwind the whole film in, say, fourteen hours, beginning at ten in the morning, man would begin to appear on the film about ten minutes before midnight! Organic evolution has been proceeding slowly for far more than five hundred million years, so we must not expect to see very much change in a lifetime.

Yet, thinking of domesticated animals and cultivated plants, it seems quite reasonable to say: If man has been able to assist in such big changes in a very short time, as geological time goes, what may not Nature have achieved in a very long time? What novelties are turning up every year among the animals we breed and the plants we cultivate! There is a welling spring of variations, a ceaseless fountain of change.

One of the most eloquent, yet driest, evolution books is Wiedersheim's *Structure of Man, an Index to His Past History* (1895), in which, with the anatomist's painstaking care, he describes the parts in our body that are dwindling—parts that once were larger and useful, that are now vestiges and more or less useless. He enumerates over fifty of these relics, so that we are very literally walking museums. It may be admitted that many of these dwindling structures in our body are what might be called trivial, but others are very striking, like the tiny third eyelid in the inner upper corner of the eye, and the slips of muscles in the ear-trumpet which exceptional people can activate, moving their ears like a donkey's. At an appropriate time it is interesting to ask the dentist about the dwindling of the wisdom tooth in civilized mankind. In many cases it never cuts the gum.

When a careful zoologist settles down to describe for the first time different kinds or species of animals, he very often comes across an interesting difficulty. He examines numerous specimens, and if they are new he makes for each a terse description or diagnosis, which will apply, he hopes, to all the members of that species. He makes careful measurements and pictures, sums up the characteristics as tersely as

he can, and then, following Adam, he gives the assemblage of specimens a name. Thus we have called one beautiful animal, which no one had previously seen, *Eumuricea rugosa*, and another kind *Eumuricea rigida*; and every zoologist who is interested in describing and classifying new animals—from the Deep Sea, for example—could give many similar instances.

So far good. But as the zoologist examines more specimens of the species, he finds, almost always, that some individuals do not fit in well. They are not *rigidas* and they are not *rugosas*, but between the two, or else divergent on a little line of their own, yet not so divergent as to deserve a special name. To read this in cold blood may not be very convincing, but when one has had the personal experience two or three times, one does not have any doubt about evolution going on.

Little novelties are probably much more important than big changes, but the occurrence of big changes should be kept in mind. The 'sporting' evening primrose, *Oenothera lamarckiana*, an American species, has given rise in Europe to numerous true-breeding 'sports' or **mutations**, which are very different from the parent plant, and are precisely comparable to different wild species. Similarly the species of fruit-fly or *Drosophila* are at present in a sporting mood, and have within a few years given rise to many very distinctive true-breeding races. Those who demand to be shown what they call 'one species turning into another'—a self-betraying phrase that discloses stretching avenues of ignorance—should give a little time to a study of the facts of mutation. Darwin believed mainly—perhaps too much—in minute new departures or fluctuating changes, which gradually increased in amount generation after generation, and were summed up eventually in a new species. The Proteus of life was not a quick-changer in Darwin's eyes. He saw a slowly changing transformation scene—*Natura repens*. But he was greatly interested in what he also got glimpses of—progress by leaps and bounds, by big mutations, as they are called nowadays. Since Darwin's day we have seen more of *Natura saltatrix*; yet the Proteus creeps as well as leaps.

In a number of cases, nowadays, it is possible to induce new departures experimentally. Thus by exposing germ-cells of the fruit-fly to judicious irradiation with X-rays it is possible to provoke many novelties in the offspring to which these germ-cells give rise. By altering the humidity, pressure, and temperature of the surroundings of potato-beetles it is possible to provoke numerous new departures, or true-breeding mutations, in a variable number of the progeny. A fascinating chapter has begun: the experimental production of new departures. The evolution of animal races through the dim and distant past cannot admit of demonstration in the strict sense, but the possibility of evolution in the present has been *experimentally proved*.

Care must be taken not to argue from changes of individuals to changes of races, but it is useful to notice how plastic individuals sometimes are. Every one knows watercress, which may grow two to four feet in length in sluggish English streams. When it was introduced into New Zealand it sometimes grew to be twelve to fourteen feet in length, with stems as thick as one's wrist.

The common spear-thistle, from two to five feet in height in Britain, formed in some parts of New Zealand vast impenetrable thickets six to seven feet in height. So it is in scores of cases, and though they only prove individual modifiability or plasticity, they are straws showing how the evolution wind might blow.

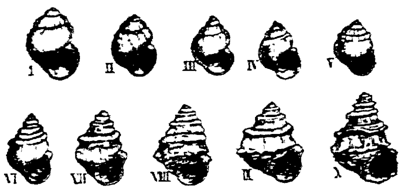

FIG. 322. EVOLUTION OF *Paludina* SHELL

I, oldest form (*Paludina neumayri*); II–IX, intermediate forms; X, latest form (*Paludina hoernesi*).

There is a long series of gradational forms between the pioneer elephants, like *Moeritherium* of the Upper Eocene, and the modern elephants, from the Upper Pliocene onwards; and so it is with the pedigree of crocodiles and camels, freshwater snails and horses. One can gather fossilized freshwater snails, beginning with the oldest, *Paludina neumayri*, and arrange them in a series of eight stages ending in the very different youngest, *Paludina hoernesi*. The intermediate forms link the beginning and the end indissolubly; and the same sort of thing is going on to-day in animals and plants, on sea and land.

The St. Kilda wren and the Orkney vole are instances of new species arising by the adding-up of variations, helped by the inbreeding which island conditions involve. In some places dark varieties of sugar-birds and of certain moths are replacing the normally coloured types; and the change is evolution going on under our eyes.

Perhaps the disbelief in actual evolution is partly due to the mistaken idea that the theory supposes that one species turns into another. But this is not the usual method of Nature's working. We have referred to this on a preceding page, but it is so important that we make no apology for repetition. From amid species A, variants arise, and these may separate themselves a little from the main body. If the variants continue varying in the same direction, and if they inbreed in some measure of isolation, they will form a new species, B, which may be particularly well-suited for new conditions. If the new conditions become more and more insistent, then species A may disappear and species B may persist, but in many cases both survive together.

Great Steps in Evolution

We are so much accustomed to thinking of animals with brains and eyes, limbs and jaws, heart and lungs, and other familiar structures, that we are a little apt to forget that all these had to be gradually gained. Once upon a time there were none of them, and the animal world was represented by minute single-cell creatures which had not even a 'body' in the strict sense. Moreover, it is as single cells that all animals begin their individual life if they are multiplied in the usual way. It is true that the fertilized egg-cell that develops, for instance, into a golden eagle or into an elephant is not really like one of the aboriginal unicellular animals, for it has condensed into it all the gains of the long past; yet none the less is it a living creature in the one-cell chapter of its history, and out of it in the individual development there come all the organs—brain and eyes, limbs and jaws, heart and lungs. Let us think of some of the great gains that were made in the course of the history of living creatures.

One of the earliest great events was *the splitting of the genealogical tree*, so to speak, into the plants and the animals, which represent two entirely different ways of living. Green plants derive their sustenance from materials at a low chemical level—air, water, and salts, which with the help of the sunlight they build up into complex carbon-compounds; and they always manufacture so much more than they need that they remain stationary and overloaded, though with astonishing powers of growth, as every tree plainly shows. But animals depend on food that has been previously worked up by plants (or by other animals that feed on plants); and they live much more nearly up to their income, having a huge expenditure on locomotion and work. Plants are the savers, animals the spenders. But, as we have already noted, there is something of the animal in many a plant, and something of the plant in many an animal. The Indian telegraph-plant works its leaflets as if it were a semaphore signal; the sedentary sea-squirt wraps itself up in a cloak of cellulose.

A second great step was what we might call exhausting the possibilities of one-cell life. There are thousands of different kinds of unicellular animals and unicellular plants—*Protozoa* and *Protophyta*—many of them extraordinarily beautiful in their living structure and in the architecture of their encasements of limestone and flint. The microscopic markings on the flinty shells of Diatoms are puzzlingly elaborate; the shells of the chalk-forming animals are decorative masterpieces. Some of the Protozoa are very active, like the Infusorians that race rapidly through the water with their living lashes, and these point the way to very active cells in the bodies of many-celled

animals, for instance to the lashing or flagellate cells that keep up currents of water through and through a sponge, or to those ciliated cells that keep our windpipe and air-passages clear. Many other Protozoa are very sluggish for part or the whole of their life, especially the parasitic *Sporozoa*, such as the one that causes malaria, and these also have their counterparts among the slow-going cells in multicellular animals—fat-cells, for instance, and gristle-cells. Between the very active and the very sluggish Protozoa there are the amoeboid forms (see AMOEBA), where the living matter flows out in finger-like or thread-like processes, used in locomotion and in food-catching. These correspond to white blood corpuscles and the like among the multicellular animals. The Protozoa may thus be thought of as blazing trails or exploring possibilities of cell-life which were followed among the units that compose the *Metazoa*.

Another great step was the acquisition of a **body**, for we can hardly speak of that when the whole creature is just one cell. A *Protozoön* is like a one-roomed house; everything that is necessary is going on within very small compass. A *Metazoön* is like a many-roomed house —some are palaces—in which there is much division of labour. The first animals to have a body were the sponges (*Porifera*), often as large as one's head; and it is interesting to notice that while they show the beginning of muscle-tissue and connective-tissue and skin-tissue, they have not yet any organs. Everything comes about gradually. The first animals to show organs are the stinging animals (*Coelentera*), where we find a true food-canal and various unified structures such as tentacles and eyes. A **tissue** is a collection of similar cells with similar functions: thus we call a piece of muscle (flesh) or fat, a piece of brain or bone, a tissue. But an **organ** is a unification of tissue or tissues for some particular use, such as holding, churning, and digesting the food in the case of a stomach, or holding and pumping the blood in the case of a heart.

It is probable that **natural death** came as a tax on a body worth having. Animals may be killed by intruding microbes or parasites; or they may come to a violent end, as most do; or they may die a natural death, which seems to be due to the mounting-up of arrears of wear and tear in the furniture of the body. It is not the living matter itself that becomes exhausted—it is rather the more or less stable framework of the cells, especially in hard-worked organs such as heart and brain, liver and kidneys. In proportion to their complexity, and that means their value, is the difficulty of keeping them in perfect repair. Rest and food, sleep and change certainly work wonders, but the processes of repair are apt to get into arrears. A holiday makes us young again, but hard work ages us; and the ageing almost always wins in the long run. Natural death is a tax on the possession

of a body—especially a body of such intricacy that complete recovery from wear and tear becomes impossible. Many animals evade the accumulation of arrears by doing things which man cannot do, such as going to sleep for the winter, or taking themselves to pieces and putting themselves together again. There are others that evade a natural death by coming to a violent end. Another animal eats them, or the temperature falls below the minimum that will allow their life to continue, or the pool dries up, or a stone crushes them. But the single-cell animals seem to be able to evade natural death in a more real way, attaining, in fact, to a kind of immortality. Since they have no 'body' to keep up, they can perfectly make good their wear and tear, and so avoid all ageing. They are not, of course, in any way exempt from violent death, for that is unthinkable; but it is much to be able to stave off all ageing. This is primarily due to their simplicity of structure, but we must also remember that unicellulars multiply very simply by dividing into two or many daughter-units. One cannot speak of death when A divides into B and C. There is nothing to be buried. How different this is from what happens with many a butterfly that dies after laying its eggs, or with big animals like lampreys and eels, that never recover from spawning.

We can only mention some of the great steps in Organic Evolution—the origin of sexual reproduction; the differentiation of males and females; the beginning of bilateral symmetry; the acquisition of blood; the specialization of behaviour; the ascent of Vertebrates; the emergence of Man.

And besides the great steps in the organisms themselves there are the weaving of the web of life, all sorts of linkages and interrelations, the peopling of land and sea, the mastery of the air, the conquest of the seasons, and much more. Yet we must not think of Organic Evolution as always progressive, for it has sometimes gone backwards or along blind alleys, but on the whole we see an increasing fullness and freedom of life.

The Pageant of Evolution

No doubt the noblest and most thrilling of all possible films would be that which disclosed the greatest events in human history. A pageant of civilization, a living outline of man's advance, a masque of progress: what cinematograph film could be more impressive and stimulating! And it could be made, as the success of sections has proved. It might be a lasting triumph of educational method, giving eye-minded young people a vision of the past which lives on in the present, and prompting the habit of thinking historically. Wanted, a dramatic presentation of Mr. Wells's *Outline of History* or a *Cavalcade* on the grand scale!

But while the pageant of human history would be the greatest and noblest film that could be made and used, we venture to think that a grander and more gorgeous one would be that which depicted the long ascent of life through hundreds of millions of years. Most striking of all would be that film which began with a vast nebula, such as the astronomers can now photograph so beautifully in the heavens of to-day.

How extraordinarily impressive it would be to see the nebular mass giving rise to stars such as our sun, and to see the sun heaving off two great spiral arms perhaps under the tide-raising influence of a passing star! How thrilling to be helped to visualize a number of knots being formed on the two colossal arms, knots which become the planets and our earth with its moon!

A conference of astronomers would perhaps agree to determine the most probable cosmogony, and clever inventors would make simulacra that could be filmed. The result would be an educational organon of incalculable value. What a gain to have our imaginations helped to visualize worlds in the making!

With the help that the genetic geologists are now able to give, it would not be insuperably difficult to make a moving picture of the mobile earth in its early phases, before it cooled enough to be a cradle or home for living creatures. We have often tried to picture the stage just before the curtain rose on the drama of life. The first section of the film would be something like this: A monotonous undulating desert, something like a stretch of sand-dunes, but cindery underfoot, and smoking at intervals. Here and there out of a crack would come a crawl of molten rock, as on the sides of Vesuvius, moving like very coarse-grained tar, blistering on the surface as it cooled, and creeping out from beneath itself in front in an ugly, sinister way. No sun by day, nor moon by night, nor any stars, but everywhere a thick curtain of Krakatoan cloud, blotting out everything; and beneath the cloud a dense unbreathable air, with much carbon dioxide, water-vapour, and nitrogen, but hardly any oxygen—the life-giver. Of course no sound or hint of life at all, nothing but hissing and sizzling, and here and there an explosion. Such was the crust of the cooling earth, perhaps a thousand million years ago.

After ages had passed, water-vapour began to condense in the depressions of the earth's crust, and the gleam of water might have been seen had there been any eye to see. Ponds became lakes and lakes merged into seas; the sun broke through the cloud-curtain. In some still unpicturable way there was an emergence of living creatures, probably very minute to start with, not well suited for filming. No doubt for a time they hesitated between being plants and being animals, but they were able to swim about and to use the sunlight to

build up carbon-compounds which formed their food; able also to liberate oxygen, the accumulation of which made higher forms of life possible.

Bucklings of the floor of the sea raised the continents, and in the shallow waters the race of fixed seaweeds began. Amongst these seaweeds, minute predatory creatures eventually appeared, feeding on the crumbs broken off from the fronds by the waves—these were the first animals.

With the help of the geologists each section of the film would be made to show the surface relief of the earth's crust at the time; the experts on the evolution of climates would give valuable assistance as to atmosphere and cloudland; from the fossil plants it would be possible to reconstruct the vegetation; the zoologist is quite capable of making his extinct animals play about the stage.

We shut our eyes and see the dense humid forests of part of the Carboniferous Period, flowerless forests of giant horsetails, club-mosses, and tree-ferns with showers of spores sinking into the swampy ground where there are clammy, cold-blooded, naked, or scaly ancestors of our present-day newts and frogs.

We try again and see in the Jurassic Period an arid country with drought-enduring vegetation and a welter of lizards and snakes and tortoises and other reptiles. Among these is a new-comer, a quickly moving, sparely built bipedal creature, about the size of a pheasant, long-toed, long-legged, long-tailed, long-necked, with a mobile head and big staring eyes. It sprints along the ground, flapping its fore-limbs as it hurries, and they bear strange integumentary outgrowths like scales partly shred out. These are the first feathers, for we are looking at the first bird.

Our film, which perhaps will materialize some day, would give to the many what some experts partially enjoy—a picture of the advancement of life. For many millions of years there were only backboneless animals upon the earth and in the waters under the earth. Then for untold ages the crown of creation was worn by Fishes! Ages pass, and towards the end of the Devonian Period there emerged the first Amphibians—the first animals to have fingers and toes, a movable tongue, true lungs, vocal cords, and other important acquisitions. Ages passed and the highest living animals were Reptiles, whence arose Birds and Mammals.

What objectivity would be given to the evolutionist's impressions of the gradually increasing mastery of life over mere things, and of the gradual emancipation of mind! But our present point is that a co-operation of geologists, palaeontologists, climatologists, chemists, botanists, and zoologists could work out the grandest of all possible films.

BOOK III

THE PLANT WORLD

CHAPTER I

GENERAL SURVEY OF PLANTS

Variety of structure—Variety of habitat—Variety of habit—Resemblances between plants and animals—Contrasts between plants and animals—A glimpse of the plant world.

THERE is great variety in the plant world—as regards size and structure, habit and habitat. In size there is a great contrast between the hyssop on the wall and the cedar of Lebanon; but the hyssop is a giant compared with the tiny mould growing on the damp bread, and the simplest plants are invisible to the naked eye. It is easier for **microbes** (microscopically small living creatures) to pass through the eye of a needle without jostling, than it is for cars to hurry along a London street without colliding.

VARIETY OF STRUCTURE

The simplest plants are single **cells** (units of living matter), but an oak-tree is built up of hundreds of thousands of cells. Between these two limits there are many levels of complexity. Thus a fern is much more intricate than a seaweed, and a moss than a mould. In the great fairs of long ago there used to be a grouping of similar booths together—all the clothiers in one place, all the tool-makers in another; and when in the course of time a town grew up, like a fair all the year round, there were streets composed of similar shops. These correspond to what are called **tissues** in living creatures, for a tissue is a combination of similar cells doing the same kind of work. Thus the skin of a leaf or of a root is a tissue, and the wood and pith of a stem are tissues. Numerous cells, similar or different, are often compacted together so that they form an **organ,** like a leaf or a root, a tendril or part of a flower. Plants have not so many organs and tissues as animals, where the division of labour is greater; but when there are many cells, it is useful in both kingdoms to distinguish: (1) the entire living creature or *organism*; (2) the larger parts or *organs*; (3) the groups of similar cells that form *tissues*; (4) the individual units or *cells*; and (5) the living matter or *protoplasm*. To make this quite clear, the comparison with a city may be used again. The organism we call an oak tree is comparable to a vast city; the well-defined parts, like leaves and roots, correspond to different quarters

in the city, such as the industrial quarter and the warehouses full of stored food; the tissues, such as the vessels in which the sap moves, correspond to streets with similar shops or houses; the cells are the individual buildings; and the living matter or protoplasm represents the inhabitants, on whom everything depends. Thus there is a five-shelved diagram:

ORGANISM	The living plant as a whole.
ORGANS	Compacted parts, like leaves.
TISSUES	Groups of similar cells, such as wood.
CELLS	Units of life.
PROTOPLASM	Living matter.

The simplest plants are single cells, not getting above the lowest shelf on the diagram. A long green thread (*Spirogyra*) from the ditch is a row of cells and nothing more; it is on the second shelf. A piece of sea-lettuce (*Ulva*) from the shore pool, like a piece of green tissue-paper, is not more than a simple tissue, the same throughout. But as we pass to plants that are less simple, there is a gradual appearance of organs, such as the holdfasts and fructifications of many seaweeds, the rhizoids of liverworts, the leaflets of mosses, the fronds and stems of ferns, and so onwards till we come to flowers, beautiful organs set apart for the continuance of the race.

So far as complexity of structure and life-history goes, the whole kingdom of many-celled plants may be compared simply to the zoöphytes and corals among animals. They are all within a comparatively narrow range. But what diversity there is between toadstool and oak tree, between the lichen on the hill-top and fields of golden wheat, between the beautifully coloured seaweeds and the flowers of the meadow! Or, if we take a single class like that of ferns, what a multitude of kinds there are, each itself and no other!

We get the same impression of endless form-changes when we study a single family of flowering plants—say the rose family. All the members have a great deal in common; they are near relations. Yet how different at first sight seem such plants as rose, strawberry, apple, and tormentil! Who would think at first sight that columbine, monkshood, and buttercup belong to the same family, *Ranunculaceae*?

Variety of Habitat

In the course of time plants have established themselves almost everywhere sometimes even on icebergs. It is most likely that they began (millions of years ago) in the **Open Sea**; and a great many minute plants, mostly single-celled, are to be found to-day near the

surface of oceans, seas, and lakes. They form part of the **plankton** (i.e. drifting) population, and are of great importance in affording food for a multitude of minute animals in the open waters. Active fishes like mackerel feed largely on small crustaceans, and these depend in great part on the **pelagic** (i.e. Open-Sea) plants.

Another great habitat is the relatively shallow, well-lighted shore area, where most of the seaweeds grow. Uppermost are the green ones, like the sea-lettuce (*Ulva*); then come the brown ones, like the wracks (*Fucus*); in the deeper water there are beautiful red ones (such as *Delesseria*), and it is believed that the red colouring matter, which masks the ordinary green **chlorophyll**, enables the plant to make more of the scantier light. It is very interesting to wade out—very carefully, because of deep holes—among the abundant seaweeds exposed at a very low tide, for one gets into the midst of a very ancient vegetation. Before there were any land plants there was an age of seaweeds. There are a few higher plants that come back again to the primeval haunts in the shore area, technically called **littoral**, one of the best known being the grasswrack (*Zostera*), a true flowering plant with even its flowers submerged. This grasswrack or eel-grass is very interesting because it has become suited to a seaweed-like mode of life. It has returned to the haunts of its very distant ancestors, and it has made a great success of the relapse. It is widely represented on many coasts, especially in temperate zones. Its long grass-like leaves are very useful in many ways, for fodder, for paper-making, for packing, for stuffing, and as a covering for Italian flasks of wine or oil. Many of the inshore fishes depend largely on the broken-off fragments of this sea-grass, whose meadows spread out only in very shallow water.

The plants of **fresh waters** are very different from those of the sea. For though there are many free-floating and free-swimming single-celled plants in lakes and ponds, and some simple freshwater Algae of higher degree, such as the common thread-like *Spirogyra*, and some primitive flowerless plants like the stoneworts (*Chara* and *Nitella*), most of the plants of the fresh waters are *flowering plants that have gone back from the land*. Round the margin of the lake there are shallow-water plants like bog-bean, mare's-tail, iris, and bulrush; further out there are water-lilies and the like that are rooted at a considerable depth, and send their leaves and flowers on long stalks up to the surface. Others, again, float freely, like the rootless bladderwort (see INSECTIVOROUS PLANTS) and the little green shoots of the duckweed (*Lemna*) which lie flat on the surface with a whitish root hanging down from each. Lemna is almost the smallest flowering plant in Britain (the rootless *Wolffia* being smaller still), but few people succeed in finding the very minute flowers, which are hidden in a

marginal groove. Most of the freshwater flowering plants are conspicuous, and the giant water-lily (*Victoria regia*) of the Amazons has a flat circular leaf six feet across; but as far as the animal life of the pond or loch is concerned, the more important plants are the minute drifters that form the plankton. They are the chief *producers* in the freshwater community and they supply most of the food for the freshwater animals—the *consumers*. When an animal dies in the water, the bacteria, which are the causes of all rotting, break down the body into salts and gases. These may be recaptured by the ordinary green plants, and thus the circle is completed, the bacteria being the *middlemen*.

Just as the sea includes the shallows near shore and the open waters far from land (and the entirely plantless abysses or great depths), so there is great variety in the freshwater haunts. 'The strict difference between a pond and a lake is not in size, for a pond may be a mile long, but in depth, for a true pond is always shallow. Then there are the lonely mountain tarns with their dark, mysterious waters and a rather sparse animal population; there are great rivers and purling brooks, swift torrents and sluggish streams with little fall; there are marshes grading into the shore, and others passing insensibly into dry land. There are also artificial fresh waters, as in canals and quarry-holes. Even in the water-supply of cities there may be a considerable number of microscopic plants' (see Thomson's *Haunts of Life*, Melrose, 1921, p. 137).

Besides the sea and the fresh waters there is the terrestrial habitat, and here we find endless variety. Mountains and moorland, meadows and marshes, links and dunes, prairies and steppes, deserts and tundra, forests and brush, what a diversity of haunts the more or less dry land includes!

And is there any plantless place except the darkness of the Deep Sea? There may be red snow, due to a very simple plant, on a floating iceberg; there are some simple plants in hot springs; there are Alpines near the snow-line on the mountains; there are moulds glistening on the underground passages in mines; there is a partner-fungus spreading through and through the heather-plant; and grave physicians sometimes speak of the flora of man's food-canal.

Variety of Habit

We mean by a plant's 'habit' the particular way in which it gets its living. Thus green plants, which are able, with the help of their chlorophyll and the sunlight, to get their food from air, water, and salts, are to be contrasted (as **holophytes**) with not-green plants that feed on rotting organic matter (**saprophytes**) or even on living organic

matter (**parasites**). Thus the mushroom utilizes the organic matter in the soil, and the leafless dodder, which loses all connection with the soil, preys upon the nettle, the whin-bush, the clover, or some other 'host.' Another peculiar habit is insect-catching, as in sundew and pitcher-plant. Similarly we may make a group of 'perched plants,' or **epiphytes,** like many of the orchids that grow high above the ground in tropical forests. They do not rob their bearers of any sustenance, so they are not to be called parasites; they simply use the other plant to lift them off the overcrowded or overshaded ground into fresh air and sunlight. The same end is attained by plants of the climbing and twining habit, such as peas, vines, hops, convolvulus, and ivy. Then there are plants like the heather and the vetches that have entered into internal partnership with fungi, without which they cannot flourish vigorously. This is the partner-habit of life, and it is very well illustrated by the lichens, for all of them are *dual* plants, an Alga and a Fungus being the two partners which work together in a mutually beneficial way. *So we see that there is in the plant world great variety in structure, habitat, and habit.*

Resemblances between Plants and Animals

For a very long time there were no living creatures at all upon the earth. That was millions and millions of years ago, when the earth was too hot to be a home of life. But the crust cooled, depressions were filled with water, and there was a heavy atmosphere of gases.

Then the first living creatures made their appearance, but we have no idea how or whence they came. What they were like, these firstlings, we do not know—almost all beginnings are very misty—but it is probably safe to say that they were microscopically small, like the microbes which cause rotting and disease. If we can imagine an observer of the earth in the time of the dawn of life, he would not have been able to see the teeming animalcules, any more than we can see the tiny specks of bacteria.

Another thing that is almost certain is that the *earliest* living creatures were neither decided plants nor decided animals. They were, so to speak, hesitating between these two very different lines of life. They were nearer plants in this way—that they were able to feed at a low level on water and carbon dioxide and salts in the water; they could build up organic matter from simple materials.

The genealogical tree of all living creatures must be thought of as like an ornamental V with little twigs on each half of its fork. To the left we may put the animals, and to the right the plants, and it would be useful to make the animal line go much higher than the plant line.

Every one feels that there is a great gulf between an oak tree and the

squirrel on its branches; but we are not quite so clear when it comes to distinguishing between a mushroom and a sponge, and some of the old naturalists thought sponges and corals were plants of the sea. Still more difficult is it to be sure whether a living creature that consists of no more than a single cell is a plant or an animal, especially as some simple animals have managed to get hold of the green colouring matter called chlorophyll—which is characteristic of the normal plants. Thus, at the foot of our V-shaped tree there are creatures, sometimes called **protists,** which the botanists and the zoologists both claim. They have not yet taken the decisive step.

Long, long ago, then, some simple, single-celled creatures manufactured chlorophyll, surrounded themselves with a cell-wall of cellulose—now sold in the shops as vegetable parchment paper—and began to build up quantities of sugar, starch, and other carbon-compounds. These were **the first plants,** and they probably lived freely in the sea. The secret of their success was the ability to feed at a low chemical level, and to use the power of the sunlight in their chemical operations of building up. Their success meant much for future history, for *they began to form an atmosphere of free oxygen,* and they made carbon-compounds sufficient to feed not only themselves but the animal world.

Of course the animals had their simple beginnings too, and the parting of the ways was when certain creatures—**the first animals**—became addicted to the habit of not building up their own food, but using what simple plants had made. This discovery of ready-made food was the deep secret of animals, and it meant the possibility of great activity, of living adventurously. For food is just like fuel; it is a supply of chemical energy as well as of body-building material.

Plants are like manufacturers of munitions, which animals explode in the never-ending battle of life. Happily for us, plants are also like misers, accumulating much more than they need; animals are spendthrifts, often living close up to their income. We can understand, then, why most animals get along comfortably without being green, and why they are nearly all free from the somewhat clogging and embarrassing material called **cellulose,** which forms the cell-walls of plants.

We have said that there seems at first sight little in common between an oak tree and the squirrel on its branches, yet there are deep resemblances. In the first place, both are *alive,* though in different ways. Both are always undergoing chemical changes, some of which are of the nature of combustions (or oxidations). If we have in a room at night a burning candle, a growing plant, and an animal such as a cat, all the three are taking in oxygen from the air and giving back carbon dioxide. During the day the intake of oxygen is disguised in green plants by the counter-process of splitting up the carbon dioxide of the air, fixing the carbon to help in making sugar and the like, and liberating

oxygen. In point of fact, most of the oxygen of the earth's atmosphere seems to be due to this power that green plants have of using the reddish-orange, yellow and blue rays of the sunlight to help them to split up carbon dioxide (CO_2), and build up carbon-compounds such as sugar. But the point at present is that plants and animals agree in using oxygen to burn up carbon-compounds in their body. This is a strange burning-up that goes on at a low temperature, and does not quickly lead to the destruction of the body. Both plants and animals show ceaseless chemical change, summed up in the indispensable word **metabolism** (the chemical processes essentially connected with living).

'Even movement, the chief characteristic of animals, occurs commonly, though in a less degree, among plants. Young shoots move round in leisurely circles, twining stems and tendrils bend and bow as they climb, leaves rise and sink, flowers open and close with the growing and waning light of day. There is likewise great sensitiveness in plants as well as in animals. Tendrils twine round the lightest threads, the leaves of the sensitive plant respond to a gentle touch, a tree may answer back to a passing cloud. The tentacles of the sundew on British moors and the hairs of Venus's fly-trap in the Carolina swamp compare well with the nervous structures of many animals. The stamens of a number of flowers, like the rock-rose, move when they are jostled by the legs of insects, and the two-lipped stigma of the musk closes on the grains of fertilizing golden dust or pollen' (Thomson's *Study of Animal Life*, Murray, London, 1917, p. 189).

Linnaeus discerned some of the deep samenesses between plants and animals, and included them both under the title **Organisata.** We repeat this when we use the word *organism* (for either plant or animal), meaning by the word not merely a living creature, but the possession of a cellular structure. As we have already said, a cell is a unit corpuscle or mass of living matter, usually controlled by a kernel or nucleus. The simplest plants and animals do not get beyond being single cells; all others are combinations of cells or of modifications of cells; and there are millions of cells in a common weed. But the **cell-doctrine** (or **cell-theory**), first clearly stated about 1838, includes two other facts. The first is that the many-celled body almost always arises by the division and redivision of a fertilized egg-cell, and of the embryo-cells thus formed. We trace an oak tree back to a sapling, and that to a seedling, and that to an acorn; but the making of the embryo within the seed is due to the division and redivision of a fertilized egg-cell. Second, each cell is a minute centre of life, and the activity of the organism as a whole is a summing-up of the activities of all the component cells. Yet a little more than the sum, we venture to say, for just as the behaviour of a crowd

cannot be adequately described except as *more* than the movements of all the individuals, especially when they are inspired by a common purpose, so the life of the plant cannot be understood if we leave out the fact that all the cells are bound together in unity. There are many members, as St. Paul said, but there is one body. In biology the whole is more than the sum of its parts.

To put it shortly, then, plants and animals agree: (1) in the essential activities of their life (e.g. in feeding and breathing, even in moving and feeling); (2) in the cellular stones and mortar of their structure; and (3) in the way in which each individual develops and grows, usually starting as a fertilized egg-cell.

Contrasts between Plants and Animals

Now let us contrast typical plants with typical animals.

(1) Green plants get their carbon-supplies from the carbon dioxide in the air or in water, whereas animals must get hold of carbon-compounds (like sugar and fat) made by other animals, and in the long run by plants. It is true that carnivorous plants, mushrooms and other fungi, and some parasites tap other sources of carbon-supply, but the typical plant gets all it needs, as far as carbon is concerned, from carbon dioxide. It is true that a few animals, such as the green bell animalcule (*Vorticella viridis*), are able to utilize carbon dioxide as green plants do, but this way of feeding, technically called **holophytic** (feeding after the fashion of a green plant), is very rare among animals. To put the case in another way, most plants have a mixture of greenish pigments called **chlorophyll,** by means of which they utilize the energy of the sunlight to build up carbon-compounds (**photosynthesis**), where as animals have very rarely any chlorophyll. A complication arises here since a number of animals, like the green freshwater *Hydra* or the green freshwater sponge, have become green by entering into a close partnership with minute Algae possessed of chlorophyll. Such animals are able to effect photosynthesis (i.e. the use of light in building up organic compounds), but they are not doing this of themselves, but through their partners.

(2) Living matter consists in great part of combinations of nitrogenous carbon-compounds, called **proteins** (such as white of egg), which are complex substances composed mainly of carbon, hydrogen, oxygen, nitrogen, and sulphur. It follows that the food of a living creature must include nitrogen-supplies. Ordinary plants obtain these from comparatively simple nitrogenous substances dissolved in water, usually in the soil. Saltpetre or potassium nitrate may be named as an example. But ordinary animals cannot get their nitrogen-supplies from anything simpler than the proteins manu-

factured by other animals or by plants. On the plant side some exceptions must be made again for carnivorous, parasitic, and fungoid plants. On the animal side, also, there are a few exceptions: thus white ants can thrive for months on a diet of filter-paper, which is an almost pure carbohydrate (*cellulose*), consisting of carbon, hydrogen, and oxygen only; and it is believed that the introduction of the nitrogenous component, derived from a slight trace of nitrogen-containing salts, is due to the intermediation of very abundant Infusorians (microscopic single-celled ciliated animals) which live as partners in the food-canal of the insects. But these exceptions are unimportant compared with the big contrast, that plants feed on *nitrates* and the like, whereas animals require *protein-food*. It may also be mentioned that animals usually give out nitrogenous waste-products such as **urea,** whereas in plants this filtering-out process is masked, unless one takes account of the shedding of leaves and other withered parts.

We may sum up the first and second contrast by saying that plants are able to feed at a much lower chemical level than is practicable for animals. We might say that plants accumulate their wealth in chemical pence, changing these into pounds, which animals get hold of and spend. Out of simple things, comparatively speaking, plants manufacture food-stuffs, such as starch, oil, and protein; animals lay violent hands on these and proceed to exploit them!

(3) The cells that build up a plant are usually boxed in by very definite walls of **cellulose,** a carbohydrate material closely allied to starch. Out of this cellulose man is now able to make all sorts of things, such as artificial silk. But in contrast to the cells of plants, those of animals have delicate walls, hardly ever with any trace of cellulose. Another point is that there is usually much more division of labour among the cells of an animal than among those of a plant. To put it pictorially, the typical plant is more like a house built of bricks, while the typical animal is like an old-fashioned cottage in the country, built of a great variety of different stones.

When we look at the contrast very broadly, we see that animals, compared with plants, live more nearly up to their income, with more liberal expenditure of energy, doing far more in the way of external work.

A Glimpse of the Plant World

We have spoken of the variety of form and of habitat among plants; another big fact, so plain that we hardly think about it, is their almost universal beauty. The exceptions are certain cultivated plants, like cauliflower and cabbage, which have lost most of the beauty of their

wild ancestors. And perhaps among the parasites, like toadstools, which do not live independent lives, there are some that are branded with a certain degree of ugliness. For beauty is the hall-mark of harmonious, healthy, well-ordered living, and it may be that, though life remains half-asleep in plants, the beautiful shapes and colours are their dream-smiles.

Think of the harebells swinging by the wayside, the wood-hyacinths, which the poet speaks of as the heavens upbreaking through the earth, the laburnums, 'dropping-wells of fire,' the daffodils dancing by the lake-side, Wordsworth's 'jocund company.' No doubt there is easy beauty and difficult beauty, but the big fact is *beauty everywhere*.

The old idea that beauty is exceptional, and hardly to be looked for save in unusual plants such as orchids, has almost disappeared; and it is well away. Many orchids are, indeed, resplendent, and often strangely suggestive of butterflies, but one cannot say that they greatly excel some of our common flowers—the violet, the butterwort, the bog-bean, the bladderwort, the grass of Parnassus, the gentian, and the daisy. The fact is that beauty crowds us all our life if we keep in touch with wild flowers; and this is a fact not less important than the statement that the central secret of the green leaf is being a sunshine-trap.

We have not learned much botany unless we have come to feel the beauty of *common* plants. The poet Keats said that throughout his life nothing moved him more than the opening flowers, and there is something wrong with us and with our science if we do not feel the wonder of the crocus breaking through the sod. But it is worth our while, also, to discover unusual thrills, to follow the stream up the gorge till we find the royal fern, glistening with spray beside a waterfall:

Plant lovelier, in its own retired abode
On Grasmere's beach, than Naiad by the side
Of Grecian brook, or Lady of the Mere,
Sole-sitting by the shores of old romance.

We are accustomed to think of strength in connection with animals and machines that move quickly about and do things and withstand assaults. The elephant, the railway - engine, the lighthouse, show strength, but we are inclined to think of the tender plant, the bruised flax, the short-lived grass, the poppy which is broken by being plucked. As every one knows, many of our gay garden flowers are annuals, lasting only for the summer.

Yet this is only one side of the picture. The grass withereth and the flower fadeth, but, after all, the grass is one of the most successful of all living things. It has covered the earth like a garment.

This power of spreading and multiplying is all very well when the

plant is on man's side, as most grasses are; but when it is an injurious plant that spreads, like bracken in this country or prickly pear in Australia, then we see the menace there may be in the strength of plants.

We are often impressed by the weight-lifting feats of the strong man at the show, but have we done justice to the quiet strength of the forest trees, which are continually sustaining enormous weights against gravity, every year adding to their burden and lifting it higher? We know the explosive power of dynamite, but it is very interesting to see the roots of a tree spreading within a cleft in the rock and after a time rending it asunder. We know of the great transformations of energy which go on in chemical and engineering works, but we must do justice to the intensity of the operations which continue unceasingly through the summer day in the chemical and physical laboratory of every green leaf; and all without a sound!

What strength of a sort there is in the way that microbes multiply, killing a king in a few hours! If one bacillus of the plague gets entrance into man through the bite of a rat-flea, it may be represented by a million the next day. What strength of renewal there is in many plants; the hawthorn is all the more vigorous because of the hedgeman's savage pruning. Then there is the strength of longevity, for the oldest living creatures in the world are some of the big trees (*Sequoia*) of California, which have lasted for three thousand years.

One of our poets is responsible for the magnificent exaggeration:[1]

Thou canst not stir a flower
Without troubling of a star.

It is but a striking way of saying that no plant lives or dies to itself. Every one of them is the intersection of numerous threads in the web of life. Let us gather a few illustrations of the part plants play in the Domain of Things, the Realm of Organisms, and the Kingdom of Man—the 'Cosmosphere,' the 'Biosphere,' and the 'Sociosphere.'

First, there is the work of plants in **the circulation of matter.** As we have explained, green plants feed on air, water, and salts; they use the carbon of atmospheric carbon dioxide as the basis for manufacturing the essentials of living matter known as starch, sugar, fats, and proteins. Some animal eats the plant, or part of the plant, and another incarnation begins. For the nutritive material obtained from the plant—the nectar the bee changes into honey, the nut the monkey cracks—becomes part and parcel of the animal's body; it is incorporated in some measure into the animal's living matter. As the animal lives it gives off carbon dioxide, and this, returning to the atmosphere, may be absorbed by a green plant.

[1] And yet, in the strictest scientific sense, it is no exaggeration, but the plain truth.

Other forms of waste from the animal pass into the soil and help to form salts which the roots of plants may absorb. Some may pass as ammonia into the air, and this may be washed down by rain into the soil, to be recaptured by the roots of plants. Or, when the animal dies and sinks to the ground, bacteria begin to work on the dead body, and it rots. Its complex substances are broken down into simple substances, such as carbon dioxide, water, ammonia, and some salts. Out of a dead bird on the ground the bacteria make materials which plants can utilize. Bacteria act as middlemen between the dead animal and the living plant. They make the materials of the dead body fit to enter again into the cycle of life; and so the world goes round.

If we pay an early morning visit to a great fishing port, such as Hull, Grimsby, or Aberdeen, we see what look like miles of fishes laid out for sale. We get a glimpse of the harvest of the sea, and the question arises in our minds: How is man able to take so much out of the sea, year after year, when he puts so little in? If he did this on the farm there would soon be exhaustion of the soil, and he obviates this on land by putting in manure. But what happens in the sea?

The answer is partly to be found in the vegetable sea-dust which is wafted outwards and downwards from the shallow water, where sea-weeds and sea-grasses flourish abundantly. Minute particles, worn off by the breakers or nibbled at by animals, are washed down the slope and form the food-supply. of fishes or of animals like the worms and molluscs on which fishes feed. It takes ten pounds of this vegetable sea-dust to make a pound of worms; it takes ten pounds of worms to make a pound of whelks; and it takes ten pounds of whelks to make a pound of rock-cod!

But the other half of the answer is to be found in what Sir John Murray called ' the floating sea-meadows ' of the Open Sea. Countless millions of diatoms and other minute algae form a sort of living sea-soup at or near the surface of the open waters. These minute organisms depend on the air and the sea-water with its salts; in the sunshine they go on with their work of building up living matter from light, like the leaves of the forest; they and some minute green animals form the fundamental food-supply of small crustaceans; and these, again, are devoured by fishes. The earth is run on a plan of successive incarnations something like this:

Air, water, and salts are absorbed by green plants in sunlight.

Nutritive carbon compounds are built up out of these, and are eaten by animals.

The animals die, and their dead bodies are decomposed by bacteria.

The decay of these bodies gives rise to gases, water, and salts.

These are absorbed by green plants again, and the cycle of life begins afresh.

A great transformation of energy is always going on in plants. The plant is a laboratory of complex chemical substances, and each has its own peculiar chemical routine, as every chemical factory has. But this work of building up could not keep going without help from outside, and it is the green plant's special secret to obtain this from the rays of the sunlight. The energy of the sunlight is used by the plant to help it in its manufacture of carbon-compounds, which have chemical energy just as gunpowder has.

Thus there is a continual changing of kinetic energy into potential energy. We see the same thing when the kinetic energy of a rush of water is used by a hydraulic machine to raise a heavy weight to a height, where it has energy of position, or *potential energy*. But what takes place in the green leaf is a more intricate transformation, and it is not yet fully known.

We shall have to do with many other ' between ' things, or **linkages.** Thus, one plant may unconsciously play into the hands of another, as when the dodder gets both support and food from the nettle; or when the mistletoe gets support and watery sap from the apple tree; or when an alga joins with a fungus to form a double plant or lichen; or when root-tubercle bacteria join in with clovers and enable them somehow to utilize the free nitrogen of the air. On another line are the linkages between flowers and their insect-visitors, which secure pollination, and the linkages which secure the scattering of seeds by fruit-eating birds. But we have made a good start towards understanding the relations which bind plants to the rest of Nature.

CHAPTER II

THE CLASSIFICATION OF PLANTS

The names of plants—Species, genera, families—Methods of classification—The uses and meaning of classification.

THERE are probably more than a quarter of a million different sorts of flowering plants in the world. About 1,500 different sorts are native in Britain and a far greater number is cultivated in gardens and greenhouses. If we are to deal with such a mass of material—whether we wish to identify the wild flower we picked up on our country walk, to make up our yearly order for the seedsman, or to examine the collection sent home by the explorer of some untrodden country—we must be able to do two things. We must be able to fix a name to each sort, and we must have some method of classifying them, or reducing them to order.

THE NAMES OF PLANTS

Many familiar plants bear the common or English names which have been applied to or invented for them during the 1,500 years' existence of our tongue; but not even all our native plants have English names. There are many grasses, for example, which are difficult to distinguish from each other, which the ordinary man has not recognized as distinct, and has not named. For the vast multitude of foreign plants, even for the fraction of these which we can grow in our country, it is obviously impossible to provide English names. And there is a further difficulty. The words 'whin,' 'furze,' and 'gorse' are used by different people for the same plant, as are also the words 'bilberry,' 'blaeberry,' and 'whortleberry.' It is difficult to fix a standard name in English. Now for scientific purposes a standard name is an absolute necessity—a name which shall have a world-wide acceptance. It is for this reason that we use Latin names. Every one is repelled by the Latin names of the plants in his garden, partly because their air of erudition makes them appear more difficult than they really are, and partly because he thinks them clumsy and ugly. They are not always so. If *Galanthus* is clumsier and less expressive than 'snowdrop,' *Heracleum* (which takes our thoughts back to Hercules or Heracles) is more dignified than 'hogweed,' and between *Ulex* and 'furze,' there is not much to choose. We are not, of course, advocating that Latin names should always be used. Where there

is a real English name we can always employ it in everyday speech. We only wish to point out that Latin names are essential for the scientific investigator, and often for the gardener as well, and that they are not really very difficult or repulsive.

SPECIES, GENERA, FAMILIES.—All plants bear a double Latin name, and this indicates the first step in classification. Let us approach the matter in this way. We all know the red currant, and the black currant, and the flowering currant. They resemble each other in being shrubs with leaves of a similar type, in having flowers of the same construction, and in bearing berries. Yet each differs from the others in several ways; the first two in the size, colour, and taste of their fruits, the last in this and in having brilliant flowers. The term 'red currant' describes a group of plants the members of which are essentially similar; and all the red currants can breed freely together. Red currants, we might say, are all the *same kind of plant*. Such a group is the fundamental one in classification and we refer to it as a **species**. The members of a species do not all resemble each other exactly; indeed, within a species there may be groups of individuals which differ from others in some minor point. The white currant, for example, has white berries; but as the white currant is exactly like the red currant in all except this minor character we do not recognize it as a separate species. Such a sub-group we call a **variety**.

Now our three currants, red and black and flowering, are distinct species, but, as we saw, they have certain characters in common; in English we recognize this fact by calling them all *currants*. This grouping of species together is the first step in classification, and such a group of similar species is called a **genus**. In Latin the first term is called the *generic name* and denotes the genus, and the second term is the *specific name* and denotes the species; there may be added a third name to denote the variety. The currants belong to the genus *Ribes*, and we can distinguish *Ribes rubrum*, the red currant; *Ribes nigrum*, the black currant; *Ribes sanguineum*, the flowering currant; and *Ribes grossularia*, the gooseberry. It might be said that this is just doing in Latin what we have already done in English. But the last example illustrates one advantage of the scientific usage. The English language has not recognized that the gooseberry is also a currant. It is somewhat different from the other three, yet any one who cares to examine the leaves, flowers, and fruits will see how similar they are to those of the others. The Latin nomenclature allows us to put it in the same genus. Moreover, it allows us to add *Ribes aureum* and *Ribes speciosum*, two species commonly grown in gardens for the beauty of their flowers, and for which no one has invented common names.

All known plants therefore are described as species and grouped in genera. But there are far too many genera to work with conveniently. So the genera are arranged in **families**, such as the *Rosaceae* or rose family and the *Liliaceae* or lily family, and these in still larger groups. In the formation and arrangement of these larger groups we encounter many difficulties, and there are, in fact, various classifications which take different kinds of characters as the basis for the grouping. Thus as regards plants we might classify them in an interesting and useful way according to their habitats—whether aquatic or terrestrial, whether marine or freshwater, whether inhabiting mountains or deserts, and so on. Or we might classify them according to their way of feeding, whether they live independently on air and soil-water, as most green plants do, or are dependent on decaying matter, as in the case of many moulds and toadstools, or prey upon other living creatures, as is the way of many bacteria. But the most useful classification is one that groups plants according to their relatedness to one another; and the relatedness is disclosed by deep-seated resemblances in structure and in development. This is what is called a **natural classification,** and it is the sort of classification we use in grouping species together in genera.

METHODS OF CLASSIFICATION.—An old-fashioned, yet common-sense, classification of flowering plants divided them into **herbs, shrubs,** and **trees**—the basis of the classification being the mode of growth. But a herb like the clover may have a near relative that is shrubby, like the gorse, and another that is a tree, like the laburnum. The pea-like flower is enough to show at a glance that clover, gorse, and laburnum are nearly related.

For many centuries various botanists tried to classify flowering plants in various ways. Many of the features they used were of no general importance. The result was a chaos of systems, on the merits of which no two botanists could agree. Then in the eighteenth century came the great Swedish naturalist Linnaeus (1707–78). He recognized that there was not then sufficient knowledge to construct a satisfactory natural system, and he set himself to provide an **artificial classification** based on characters, such as the number of stamens, of minor importance in determining real relatedness, but of easy recognition and application. Linnaeus had a genius for putting things in order (he even classified botanists) and an incomparable gift for writing terse and snappy Latin descriptions. So successful was he that his classification came into universal use for more than a century; Erasmus Darwin, the grandfather of Charles, even wrote a long poem on it in order to introduce it to the young ladies of England!

During the last century many botanists—two of the great names are Hooker and Engler—have laboured to construct a universally

acceptable natural system. Even now this aim has not been fully reached, but the general lines of the grouping of plants are now understood.

The broad lines of plant classification are familiar. For every one recognizes that the **Flowering Plants** stand apart from the **Flowerless Plants.** Among the flowering plants the great majority of different forms are **Dicotyledons,** with two seed-leaves or cotyledons, as in the pea-like, rose-like, maple-like, and cress-like forms. A minority of different types, the **Monocotyledons,** have one seed-leaf, as in grasses, palms, and lilies.

For a beginner difficulties arise when he scrutinizes some puzzling plant, like the duckweed (*Lemna*), where the flowers are so minute and simple that they are not easily found. There is a good exercise in classification—to prove that the duckweed which covers the pond with its tiny green disks is really a flowering plant. And there are not a few other cases where the flowers are well hidden away.

Another difficulty is with the cone-bearing plants like pines, firs, yews, and junipers, for every one knows that they have none of the petals and sepals which we usually associate with the word ' flower.' Moreover, if we pick a cone to pieces, as the bird called the crossbill often does to get at the seeds, we notice that the upper surface of the base of each hard scale bears a couple of seeds, which are naked and not shut up in a seed-box as in ordinary flowering plants. Yet the cone-bearers are often grouped with the flowering plants. It is safer perhaps and simpler to take a definite character which they have in common, that of bearing seeds, to distinguish them from the lower classes with neither flowers nor seeds. Monocotyledons, dicotyledons, and cone-bearers may thus be called **Seed-plants** or **Spermophytes.** The monocotyledons and dicotyledons may be grouped together as true **Flowering Plants** or, better, **Angiosperms,** plants with enclosed seeds, while the conifers and their allies are grouped as **Gymnosperms,** plants with naked seeds.

Below the level of the seed-bearing plants there are numerous classes such as ferns and horsetails, mosses and liverworts, seaweeds and toadstools. These have certainly no flowers, and it used to be thought that their mode of reproduction was more obscure than that of the flowering plants with their conspicuous stamens and carpels. So they were all grouped together as **Cryptogams,** in contrast to the seed-plants, which were called **Phanerogams.** In the light of the research carried out in the last century we now know that the detailed processes of reproduction in the phanerogams are really much more hidden than in the cryptogams, so that these names are not really descriptive. But they are sometimes convenient to use and are often found in botanical books.

The higher seedless plants are the ferns, horsetails, and club-mosses. These are often called **Vascular Cryptogams** because they show more or less development of woody tissue, the chief feature of which in the flowering plants, is the *wood vessel*. The living representatives of the vascular cryptogams are the ferns, the horsetails, and the club-mosses, but there are many fossil relatives which have left no living direct descendants to-day. Some of them have been of great practical importance to man, for their remains have formed the bulk of the coal measures. That is to say, we warm ourselves and drive steam-engines to-day by means of the chemical energy of these ancient plants, and that in turn was due to the sunlight of those distant ages. For the energy of coal is imprisoned sunshine.

As the higher cryptogams are more or less fern-like they are called **Pteridophytes,** and they are contrasted with the simpler mosses and liverworts in being emphatically vascular, and in a feature in their life-history which we shall describe later. The mosses and liverworts are grouped together as **Bryophytes.** There is a very sharp distinction between mosses and ferns, and indeed this is one of the great gulfs in the kingdom of plants. The simple liverworts are perhaps the nearest descendants of the first land plants.

At a still lower level are the two great classes of **Algae** (seaweeds) and the **Fungi** (moulds, mildews, and toadstools). Both are often included under the name of **Thallophytes,** for they show no clear separation of the plant into leaf, stem, and root. In other words, they consist mainly of 'thallus.' One is tempted to say that a big pennon-seaweed, like *Laminaria* at low tide, shows an attaching root, a firm stem perhaps a yard long, and an expanded leaf. But the 'root' is only an anchor and not an absorbing organ, and neither it nor the stem shows much difference in internal structure from the 'leaf.'

In most fungi the plant is a web or tangle of delicate threads, but from these there may arise complicated reproductive bodies familiar to us in the mushroom and toadstools. Although they have nothing to do with true fruits, these reproductive bodies are often familiarly and conveniently spoken of as *fructifications* or *fruiting bodies*. Many toadstools are brilliantly coloured, but the class of Fungi is marked by the absence of chlorophyll, the green pigment which is characteristic of all other plants. It follows that fungi cannot carry out photosynthesis, and must therefore be dependent on organic substances formed by other plants or by animals—organic substances which may be utilized either in a living body or in a dead one. Thus the fungus of salmon disease (*Saprolegnia*) battens on the tissues of a living salmon which has been previously infected by a unicellular microbe; whereas the mould we see on horse-dung is obviously feeding on decaying matter. Similarly the potato-disease fungus (*Phytophthora*) battens

on the living plant while the bread mould (*Mucor*) is feeding on what is no longer within the circle of living things.

Some of the algae and fungi are single cells, but the majority are filaments, networks, fronds, and the like, consisting of many cells which do not, however, usually show much differentiation of form or division of labour among themselves. But there are some unicellular plants so distinctive that they deserve to be separated off in a group by themselves. We refer to those simple plants, the **Bacteria,** which some authorities group along with the Fungi.

As for the **Lichens,** common on the branches of trees, and on the stones of road-side walls, it is agreed that these should be regarded as partnership plants, each consisting of a particular alga living in symbiosis (mutually beneficial internal partnership) with a particular fungus.

So we reach the base of our classification, ending with what was really the beginning, namely, the simplest plants; and under this title we propose to rank the simplest unicellular algae and fungi. Various types still more primitive may be thought of as at the very base of the V-shaped genealogical tree, for they are not very definitely plant or animal, but hesitating as it were between the two. Let us repeat in a detailed scheme our general classification. It should of course be read from below upwards.

I. SPERMOPHYTES or PHANEROGAMS (Seed-plants):
- (1) **Angiosperms.** True Flowering Plants with seeds enclosed in fruits.
  - (*a*) **Dicotyledons,** with two seed-leaves, e.g. buttercup, rose, daisy.
  - (*b*) **Monocotyledons,** with one seed-leaf, e.g. lily, palm, grass.
- (2) **Gymnosperms.** Cone-bearing Plants with naked seeds, e.g. pine, yew, sago-palm.

II. CRYPTOGAMS (Seedless Plants):
- (1) **Pteridophytes** (Vascular Cryptogams), e.g. ferns, horsetails, club-mosses.
- (2) **Bryophytes,** e.g. mosses, liverworts.
- (3) **Thallophytes.**
  - (*a*) **Fungi,** e.g. mushroom, mildews, moulds.
  - (*b*) **Algae,** e.g. wrack, kelp.
  - (*c*) **Lichens.**

THE USES AND MEANING OF CLASSIFICATION

A system, as we have said, is necessary if we are to be able to deal effectively with the multiplicity of plants which cover the face of the earth and inhabit its waters. Its use is at once apparent when we come to deal with the commonest problem that confronts any one interested in wild flowers—the problem of finding the name of some new plant

picked up on a country walk. Plants are described in books called **Floras.** Two good floras of the British Isles are Hooker's *A Student's Flora* and Bentham and Hooker's *A Handbook of the British Flora.* Watts's *A School Flora* is perhaps easier to work with, but has the disadvantage that it does not contain descriptions of all our plants. A convenient book of illustrations is Fitch and Smith's *Illustrations of the British Flora.*

Had we no method of classification we might have to read through several hundred pages of descriptions to find one to suit our plant. As it is, we can turn to a synopsis of families at the beginning of the flora and with relatively little trouble find that to which our plant belongs. Turning to that family in the body of the work we find it prefaced with a synopsis of the various genera it includes, and from this we can find the genus. Finally, under the genus we can read the descriptions of the various species, and select that which best fits the plant that is new to us. The process is not quite so easy as it may sound. Floras are written in technical language, and the technical terms must be mastered. They are just as necessary for scientific work as are Latin names, for only with their aid can short and accurate descriptions of a multitude of plants be given. Further, the differences between closely related species are often rather obscure, and the characters of the plants themselves are somewhat variable. Any one seriously interested in flowers must set himself to conquer such difficulties: with practice they diminish greatly. Others will find help in more popular floras easier to work with, because usually based on some easily applied artificial system such as the colour of the flowers; these have always the disadvantage that they cannot deal adequately with all the species which may be found.

Finding the names of foreign plants—and of many of the plants in our gardens which are foreign in origin—is a much more difficult matter, and is often possible only to those who have access to the libraries and herbaria (collections of dried plants) existing in some of our universities and at the great botanical gardens, such as those at Kew and at Edinburgh.

Apart from its practical applications the science of classification or **Systematic Botany** has another interest of a very different nature, which we have indicated incidentally. We may ask ourselves the question: What do we mean when we say that plants are related? I am related to my sister and to my cousin by the ties of blood and common descent. What ties unite a buttercup and a larkspur? The theory of **Evolution,** established as a working hypothesis by Charles Darwin, and now recognized as one of the great biological truths, tells us that here too the relationship is that of common descent. From extremely remote common ancestors flowering plants are

descended. In the course of millions of years the succeeding offspring of early forms have diverged more and more from each other in multitudinous directions, producing the diversity we see to-day in our woods, fields and gardens. Stocks that diverged early in this history have become very different; later changes have produced groups whose members show greater similarity among themselves; the latest developments have given us those little clans of species we call genera, so closely similar that their relatedness leaps to the eye. And the relationship throughout is a real one of blood or, should we say, sap, and common ancestry.

In classifying, then, we try to find a natural system which shall express the facts of a **real relationship.** Furthermore, in our classification we try to sketch the course which we believe evolution to have taken. For prolonged study has convinced us that some of the families we have to-day are more primitive in character than others. They are stocks which have retained throughout countless years features long since abandoned by others. Thus we usually place the buttercup family at the beginning of the dicotyledons, and the daisy family at the end, for we have good evidence that the buttercups represent a very ancient family and the daisies a comparatively modern one.

Evidence of many kinds is used in such studies; but with all that is available our knowledge is still too limited to make us sure of all our conclusions. Yet this fine aim is always before the systematic botanist—to make his system such as will express not only relationship, but also the course of evolution which has led to that relationship. And from the apparently dry page of a flora filled with technical descriptions of a mass of species the botanist can conjure up a vision of the pageant of evolution working incessantly through aeons of secular history to people the earth with its ordered diversity of creatures.

CHAPTER III

THE ALGAE

The Green Algae—The building of a body—The Stoneworts: Chara—The Diatoms—The Brown Seaweeds: Phaeophyceae—Alternation of generations—The Red Seaweeds: Rhodophyceae—Seaweeds as food—Fossil Algae.

The Green Algae

In an open rain-tub or tank of fresh water we may often observe, especially in spring, that the water takes on a greenish tinge. This is due to the presence of myriads of one of the simplest of plants, an alga called *Chlamydomonas*. It will be readily understood that for organisms which are invisible to the unassisted eye we have no familiar names. The individual Chlamydomonas can be seen clearly only with a fairly powerful microscope. It is to be observed as a little pear-shaped object moving about with great rapidity, and consequently difficult to make much of in the way of detail. If one of them gets caught on some chance grain of dirt and cannot move, it can be examined more easily. It is about one-thousandth of an inch long; five of these individuals placed end to end would make up the thickness of this paper. The power of movement is due to the possession of two **cilia** or lashes attached at the front or narrow end. So delicate are these, and so rapid their flailing sweep, that they can no more be seen in the living organism than the propeller in a moving aëroplane. The most conspicuous thing about this little plant is its green colour. The pigment is not evenly diffused through it, dissolved in the living substance, but is present only in a sharply defined zone, lying within the cellulose wall, and leaving a colourless region at the front end. The green pigment is the **chlorophyll** which is characteristic of all normal plants, and it is always confined in this way to a definite organ within the cell which we call a **chloroplast**. The chloroplast of *Chlamydomonas*, like that of most algae, has a denser region called the **pyrenoid**, in which the starch manufactured in photosynthesis is stored.

The chloroplast is embedded in an almost colourless mass of viscid matter. This is the **protoplasm**, an extremely complex mixture of various organic compounds in which proteins bulk largely. The protoplasm is the actual living matter of this as of all organisms, and in it there take place the varied physical and chemical changes associated with the life of the plant. In the unit of protoplasm,

conveniently called the *protoplast*, there is a blob of denser jelly, the nucleus. It appears to regulate the activities of the protoplast, though how this regulation is carried on we do not know. It is also the seat of the hereditary characters of the organism which are carried over from generation to generation. At the apex of the protoplast are two tiny drops of watery fluid or **vacuoles**, which may be seen to contract and expand or pulsate, and which may have something to do with getting rid of waste matter, i.e. with **excretion**. The whole organism is enclosed within a delicate but firm membrane of **cellulose**, the stuff which we use in an almost pure state as cotton-wool. This enclosure in a cellulose wall is an almost universal character of plant-cells. Through this wall protrude at the apex the two cilia. Near the apical end is a small bright-red spot, the *eyespot*, the function of which is obscure.

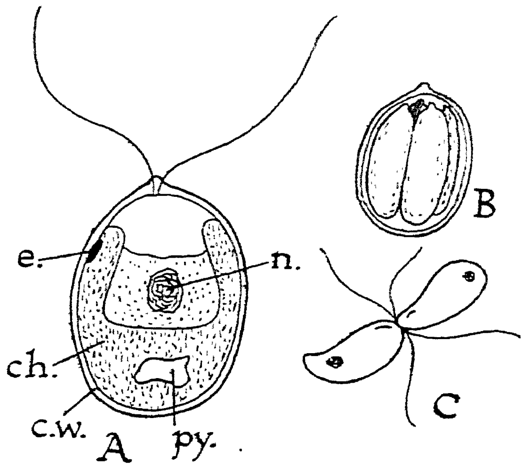

FIG. 323. *Chlamydomonas*, A UNICELLULAR ALGA
A, Diagram showing structure; *e*, eyespot; *ch*, chloroplast; *cw*, cell-wall; *py*, pyrenoid; *n*, nucleus. B, Individual which has divided internally into four daughter cells. C, Fusion of two sex-cells.

It will be appreciated that this little plant includes in its microscopic bulk a complex structure—and we have not even yet described all its details. Chlamydomonas is, in fact, a single representative of the units of which all higher plants and animals are constructed, each unit being called a **cell**. In the plant-cell the essential parts are normally the **wall**, the **protoplast**, the **chloroplast**, the **nucleus**, and the **vacuole**. These are all present in the single cell which constitutes this simple plant. In addition Chlamydomonas possesses, what most higher plants lack, the means of locomotion, of moving freely about, namely, its two cilia. Its vacuoles, too, are peculiar in being contractile, for this is rather an animal character. In these two points it shows a relation to the animal kingdom, and indeed at this stage of evolution the differences between the two kingdoms tend to be less sharply marked than at higher levels. We are perhaps in a region where a common stock from which both kingdoms arose is not far distant. But in its chloroplast with its power of building up food from

inorganic material, and in its cell-wall, Chlamydomonas is entirely plant-like.

We may note here that Chlamydomonas does not swim about at random, as it appears under the microscope to do. Its movements are *directed* and serve to bring it into conditions where it may live normally. An interesting and simple experiment proves this. If some water, greenish with Chlamydomonas, is placed in a glass near a window, it will be found that, in a very short time, the side of the glass next the light becomes covered with a green deposit. The alga has swum to the light and clustered on the illuminated wall of the vessel. Light is necessary for photosynthesis, and the alga has swum towards the best light available.

The green colour of the water is due to the presence of a myriad of individuals, and Chlamydomonas often develops with surprising rapidity in the course of a day or two. This means that the organism multiplies with extreme rapidity. How is this multiplication or **reproduction** carried out? The fact of reproduction is one of the great characteristics of living things, and it takes place in many fashions. Even so simple a being as Chlamydomonas shows something of its variety. Most simply the living matter within the wall splits up into two to eight parts, each provided with a portion of the chloroplast and of the nucleus. These new parts slip out of the old cell-wall and grow rapidly in size, each acquiring two cilia and a cell-wall for itself. Such unicellular bodies formed for reproduction are called **spores,** and since these are motile they are distinguished as **zoöspores** (i.e. animal-like spores).

Sometimes, probably in response to obscure changes in the nutritive conditions of the environment, there are formed within the old cell as many as sixty-four small bodies, each like a zoöspore. These, however, when they escape, cannot grow directly into new individuals. Before this can happen they approach each other in pairs. Two of the little bodies become entangled by their cilia, and then completely fuse together. The resulting body rounds off and covers itself with a thick cell-wall, and then goes into a state of rest, in which it is very resistant and can withstand drying up. After a longer or shorter period of rest it divides internally into a number of zoöspores, each of which grows into a new Chlamydomonas.

Here we have an early aspect of one of the most important of all the processes of life—**sexual reproduction.** The essence of the matter is that reproductive bodies are formed which before they can develop must, as it were, unite forces and so take on a new lease of life. The sexual reproductive bodies are called **gametes,** and the result of their fusion is called a **zygote**; when the zygote is, as here, a resting stage it is called an **oöspore.**

Certain species of Chlamydomonas show a definite advance on the simple process just described. One individual loses its cilia and ceases to move; another divides into a large number of gametes; one of these slips into the wall of the first and fuses with it. Here we have a differentiation into a large non-motile female gamete—an **egg-cell or ovum,** and a small motile male gamete—a **sperm-cell.** Among the advantages thus obtained we may note that, in being large and passive, the egg may become well nourished and better fitted to give the new generation a good start in life; the function of finding the egg-cell and ensuring fusion falls on the sperm, which tends to be small and very active. With the change to a large and passive egg and a small and motile sperm comes the idea of the fusion as a process of **fertilization,** in which the male plays the active part and causes the female to develop. The term 'sex,' too, is felt to be more appropriate where there are *two* sexes. But the root of the matter is the *union* of two reproductive bodies.

Associated with the reproduction of Chlamydomonas is a feature which we find again and again throughout the plant kingdom in this connection—the provision of a **resisting** and **resting stage** in the life-history. The delicate cells of the alga living in water are easily damaged by extreme heat and cold, but their chief danger is drought. In the air they shrivel in a few minutes and die. Yet living in small, chance pools of water they are in constant danger of this happening to them. Over such danger the resistant oöspore carries them, for it can be dried to dust and still survive. The dust left at the bottom of the pool may be scattered by the wind; the spores may be carried far and wide in the air, and they may come to life in a pool far distant from the first. Here is another process often associated with reproduction —that of **dispersal.** Rest and resistance go together. The rest is a passive one—we would say that from it the organism derives no direct benefit, no refreshment, as we do from sleep. The rest of plants is just the capacity to reduce all activity to a rate infinitesimally slow compared with the normal, so that the substance on which life depends is conserved during a period when it cannot be renewed.

We have spent some time over so inconsiderable a being as Chlamydomonas. But it is well worth while, for it shows us in small compass many of the characteristic activities which we find throughout the plant kingdom, and it shows us the sort of beginnings from which that kingdom has sprung. Let us sum up by saying that in Chlamydomonas we have a plant so simple that it consists of but one of the units of which other plants are constructed; this unit, however, shows all the essential characters and activities of the cells of higher plants. In its nutrition it is a true plant. In its power of free motion it betrays an animal relatedness. In its reproduction it shows the

beginnings of the two great types, the **sexual** and the **asexual**, which play so great a part in the evolution of the plant kingdom.

Some algae on the same level as Chlamydomonas are more familiar than it is. *Protococcus*, which powders with green dust the north side of beech and other trees, is even simpler. It is an alga which has taken to land life. It can do with little water and can resist even desiccation by sinking into a temporary quiescence, but without forming special thick-walled spores. The north side of trees is its favourite dwelling-place because that side tends to be moister and cooler than the south. It is non-motile; cilia would be useless to a cell living on dry bark. Its reproduction too is simpler; generally it divides into two, each half retaining a portion of the old wall. Often the two halves stick for a time together and little groups of loosely united cells are built up; but these have no common life.

Another conspicuous alga is *Haematococcus*, a genus much resembling Chlamydomonas, but possessing in addition to its chlorophyll an orange pigment of the same nature as the **carotin** which colours carrots and tomatoes. When abundant it gives small rain-pools a reddish tinge, and a closely related species with the power of growing at low temperatures occasionally gives rise to patches of red snow in Arctic lands.

The Building of a Body

Most algae are less simple than Chlamydomonas, and among the green algae we may study from the beginning the ways in which complexity of structure has been reached. Three different plans have been tried, but only one of these has led to complete success and has become standardized, as it were, among the higher plants.

THE COLONIAL TYPE.—The first method was the attempt at the federation of a number of cells by the formation of a colony. *Volvox* is the best-known example of this. Compared with Chlamydomonas it is very large—as big as the head of a small pin, and quite easily visible to the naked eye. In a glass of water from a pond we may occasionally make out its tiny spheres spinning up and down and round and round in ceaseless motion. Each is a hollow ball of jelly, and in the jelly are spaced out at regular intervals thousands of cells; each cell is in essence a small Chlamydomonas provided with chloroplast, cilia, and nucleus; each is linked to its neighbours by a delicate strand of protoplasm. There may be 20,000 cells in a colony. Here we have an association in which there is clearly liaison between different cells or individuals, and this is shown in behaviour as well as in structure. For the Volvox colony swims in a directed fashion governed by light, as does the cell of Chlamydomonas; now if all its

constituent cells were independent of each other, a co-ordinated beating of their 40,000 cilia would be impossible. Moreover, though Volvox is globular it possesses a definite front and rear, related to the way in which it develops. In reproduction, only some of its cells divide up to form daughter-colonies; the rest remain vegetative. In some colonies sexual reproduction takes place. In these, again, certain cells

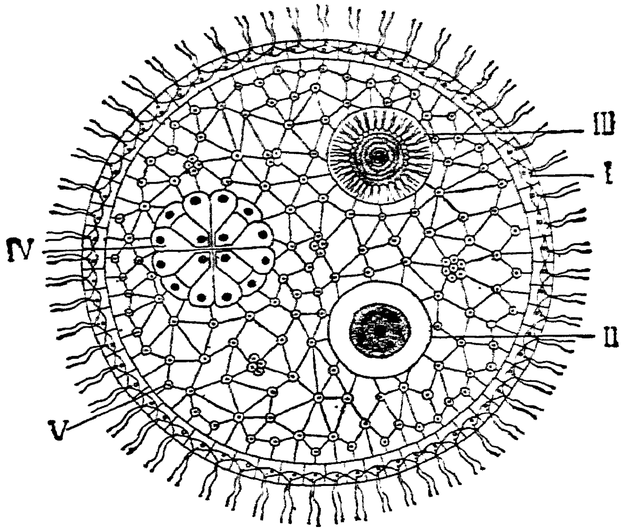

FIG. 324. *Volvox*, A COLONIAL ALGA
I, Vegetative cell at periphery of colony; II, egg-cell; III, cluster of sperm-cells; IV, daughter colony; V, surface view of vegetative cell.

produce many minute sperms, and others grow large and form non-ciliated ova. The majority, however, do not take part in the reproductive activity. Thus we have advanced not only to a federation of many cells, but to one in which a considerable differentiation between the constituent cells has taken place.

We may think of a colonial form like Volvox as having evolved through a failure of the spores of a Chlamydomonas-like type to separate after division. Such a state of affairs we have already seen in a very elementary form in Protococcus. The idea is made easier when we know that there are colonial forms much simpler than Volvox; one indeed, *Gonium*, has but four cells. But failure to separate is a negative sort of quality, and the evolution of a Volvox involves more than this. It has made positive advances in differentiating and

integrating its component cells. Yet along this line no further advance has been possible. Volvox is the most complex plant we know with the colonial type of construction; the limits of co-operation within so loose an organism have apparently been reached.

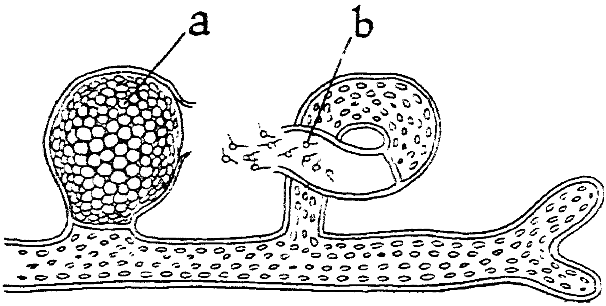

FIG. 325. *Vaucheria*, A FILAMENTOUS ALGA
a, Large egg-cell packed with oil-globules; *b*, escape of active sperm-cells.

THE HOLLOW-TUBE TYPE.—A second peculiar line of advance is exemplified by a common alga called *Vaucheria*, which is probably familiar to most people as a green felt on the pots and soil in damp greenhouses; other species are found in ponds and streams. It is unfortunate that so many of the green algae are so similar to the naked eye; green tinge in water, green scum on the pond, green dust on a tree, green felt on damp soil, we know them all, but, without the eye of the microscope, we cannot see how they really look, nor can we realize that each may include many different and beautiful forms.

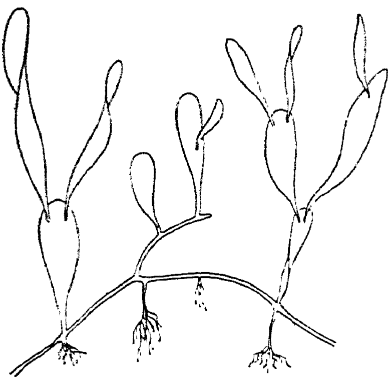

FIG. 326. *Caulerpa*

Vaucheria consists of long branched and matted threads, each the thickness of a coarse hair. Each thread has a wall of cellulose, lined with protoplasm, and enclosing a watery solution in the immense vacuole which makes up most of its bulk. In the thin layer of protoplasm are embedded many very small, biscuit-shaped chloroplasts, and many small nuclei. This is a plant in which a common wall houses the essential parts of numerous cells; a common hall in which individuals live without cubicles of their own. But the individuals have lost,

with their walls, their identity, and only their contributions of chloroplasts and nuclei indicate their presence. Vaucheria produces large asexual spores with many cilia, and it also reproduces sexually. Large motionless egg-cells are fertilized by small sperms, each with two cilia, and a resting oöspore is formed.

The housing of a multitude of cells within a common wall has led to the evolution of some remarkable plant forms. Plants of this kind are fairly numerous, and most are seaweeds. There are not many of these on our British coasts, but some are common in the Mediterranean. Perhaps the most remarkable is the genus *Caulerpa*, which grows on the sheltered side of rocks and reefs in rather shallow water. The different species of this genus resemble in size and outward form various higher plants. One is like *Selaginella*, often grown in greenhouses; another is like the sandwort-spurrey, common on our dunes. They have root-like anchoring organs, branching stems, and expanded pseudo-leaves. But structurally they resemble Vaucheria; a stout wall encloses a continuous cavity lined with protoplasm and filled with water. Strength is given by curious ribs and girders. Caulerpa is perhaps the most striking example of one organism bearing an external resemblance to another to which, in everything essential, it is totally unrelated. It illustrates the highest level reached on the hollow-tube plan of structure. More varied in form, much greater in size, and more numerous in different types than the colonial plants, the tube plants have not reached any higher level; their evolution has ended in a blind alley.

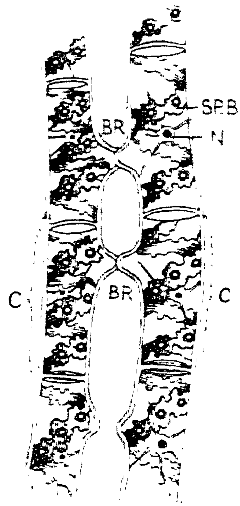

FIG. 327. TWO THREADS OF *Spirogyra* CONJUGATING
C, single cell; BR, conjugation canals; SP.B, spiral chloroplast; N, nucleus.

THE CELLULAR TYPE.—It was along a third line of evolution that the full possibilities of greater elaboration were realized. The third plan is seen in its simplest form in a great variety of green freshwater algae, which consist of filaments of the thickness of a hair, sometimes branched, sometimes not, and, to the naked eye, not very different from Vaucheria. A beautiful alga common in ponds, especially where the water is soft, is *Spirogyra*. The threads have a gelatinous coating which makes them slimy to the touch; they are unbranched. They are divided by cross-walls into a series of compartments, each several times as long as broad. Each compartment contains a lining of protoplasm,

a single large nucleus, a large central vacuole, and one or more conspicuous chloroplasts, each in the form of a ribbon with ragged edges, wound in a spiral within the wall. These spiral chloroplasts give the alga its name, Spirogyra, and in some of the largest species they are just visible to the naked eye. It will be realized that each such compartment corresponds exactly to the single cell of Chlamydomonas. It differs in shape, size, and chloroplast form, but all the essential parts of a cell are there. These cells are capable of division. The nucleus divides into two; the two halves separate and between them

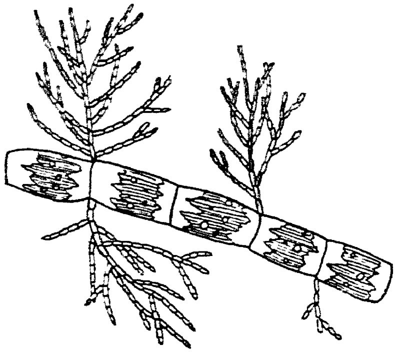

FIG. 328. *Drapernaldia*, A BRANCHED FILAMENTOUS ALGA

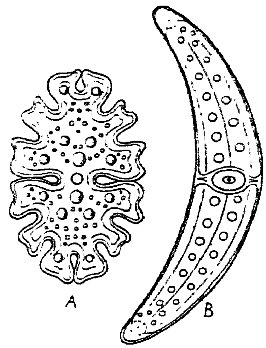

FIG. 329. TWO TYPES OF *Desmid*
A, *Euastrum*; B, *Closterium*.

a new cellulose cross-wall is formed. But the two cells which thus arise do not separate except as the result of accident; they remain as part of the filament. The filament is an organism built up of cell units. It differs from Volvox in that the constituent cells are closely applied to and united with each other. In some ways Spirogyra is not so highly evolved as Volvox, for its cells show no differentiation, and, if the filament is accidentally broken up, each is capable of independent life. Yet in such a simple form we have the essentials of all higher plant structure—the close union of a number of cells.

The reproduction of Spirogyra is peculiar. Two filaments lie side by side. Two opposite cells send out little projections which meet and form an open connection. Through this canal the contents of one cell pass into the other, and the two fuse, forming a resting zygote. When this germinates its thick coat bursts and a new filament is formed by growth in length and the formation of many cross-walls. Here we have a first example of a multicellular or many-celled organism arising in the course of development from a single cell.

Many other algae common in fresh water have similar structure.

There are great differences in the size of the cells, in the form of the chloroplasts—rings, plates, bands, or stars—the presence or absence of branches, and so on. Many of these algae show, too, a definite beginning of cell-differentiation. There may be a colourless basal cell fitted into the roughnesses of a stone and acting as a rhizoid to keep the plant in position against the flow of the stream. There may be long hairs. In one beautiful form, *Drapernaldia*, a main axis of large cells supports whorls of branches of smaller cells, the relatively large chloroplasts of which proclaim them as specially adapted for photosynthesis.

FIG. 330. *Ulva*, THE SEA-LETTUCE

Above all there is variety in reproduction. Spirogyra is exceptional in its mode of **conjugation.** This is seen also in the unicellular *Desmids*, a group common in the water of peat-mosses, and regarded as specialized and reduced forms derived from the Spirogyra stock. Much more commonly the filamentous algae form gametes of which one at least is motile. In some there are *equal* gametes, like those of Chlamydomonas; in others there is a larger, though still motile egg-cell; in yet others the egg-cell has become passive, and remains at rest in the parent cell, where it is sought out and fertilized by the active male. The result of all such unions is a thick-walled oöspore which, after a period of rest, germinates, often by producing a number of zoöspores which in turn grow into new individuals. Zoöspores are also frequently formed as asexual reproductive bodies in the cells of the filament itself. In a general way we may say that these zoöspores are suited to a rapid and certain multiplication of the species, for they do not depend on the somewhat fortuitous occurrence of fertilization for their further growth. The sperms and egg-cells provide that periodic fusion of two stocks which seems to mean so much for the continued vigour of the race.

The formation of motile spores and gametes in the sedentary filamentous algae is interesting from another point of view. Zoöspores and sperms are singularly like Chlamydomonas individuals; their existence is a clear indication that the filamentous algae, in all their diversity, have had their origin in a free-swimming unicellular stock

of the Chlamydomonas type. In their reproductive cells the filamentous forms bear the mark of their origin.

One further advance in complexity is shown in the group of green algae, and is exemplified by that familiar seaweed the sea-lettuce or *Ulva*. In it alone, among those we have so far mentioned, there is a plant large enough, common enough, and definite enough in its form to have earned an English name. It may be found abundantly in rock pools or washing about on sandy beaches. It is an irregular, crumpled, thin, green plate as large as the hand or larger. It consists of two layers of cells, very similar in form and in the shape of the chloroplasts to some of the filamentous types. It is similar too in its mode of reproduction. It is in fact a filament which has grown in three directions instead of one, in breadth and thickness as well as in length, and so has produced a **thallus.** This we can define as a plant body which has not yet attained to definite differentiation into leaf, stem, and root. With its production we begin to get a glimpse of the possibilities of the cellular mode of construction. A cell can divide by a wall set in any direction. If the new cells remain attached to each other, then there is the possibility of building up structures leaf-like in form and leaf-like in their function of efficient light-absorption and photosynthesis.

Further than this the green algae have hardly gone. They live in water, mostly in fresh water, and only a few have advanced to damp ground as a habitat. In the sea we shall meet with other groups of algae far more complex than any of the green forms. It might be thought that the sea has therefore been a much more favourable ground for the evolution of algal stocks. But there is another way of looking at the matter. The green algae are typically the inhabitants of fresh water, and their most obvious line of advance was to occupy the dry land. If they do not appear to have done so, this is probably because the vigorous and successful emigrants became, in the process of conquering, something else; so successful were they that they ceased to be algae and formed the beginnings of the great groups of the land flora. For, though there are no certain links between the lowly green algae and, say, the ferns, there is little doubt that it was from the former that the latter arose.

The Stoneworts: Chara

There are two peculiar groups of algae which we may consider here. Neither of them shows very close relationships to other forms, but both are probably highly specialized offshoots.

In shallow pools and lagoons of brackish water the bottom is often covered by a thick growth of the stonewort (*Chara*), each plant six inches or more in height and rather like a little Christmas tree with

its whorled clusters of branches. Sometimes they have a normal green colour; sometimes they are white with a coating of calcium salts—a habit which has earned them their English name. Here is another alga so large and of so striking a form that it has been recognized by the man in the lane.

The plant is rooted in the mud and consists of a supporting axial row of cells, each covered by a skin of smaller cells. The cells of the axis are often more than an inch long and as thick as a coarse needle—enormously larger than plant-cells usually are. Between each pair lies a knot of small cells and from this there springs the whorl of branches, always the same in number. The structure is interesting in the geometrical regularity with which it is built up, and this extends to the very complicated reproductive organs—large enough to be seen as little yellow or orange globules or flasks—in which the small motile sperms and the large egg-cells are formed. The stoneworts have a peculiar fetid odour said to be repulsive to mosquitoes. In the tropics attempts have been made to investigate the possibility of using Chara as a preventive of the pest. The species of Chara are widespread and, where they grow, are often very abundant in individuals. Yet despite this success they stand quite apart from all other algae and indeed from all other plants. We have no evidence as to the stock from which they have arisen and it is probable that they are extremely ancient. Fossils resembling them occur in almost the earliest of plant-bearing deposits. They do not seem to have given rise to any higher forms. We might hazard the conjecture that the very regularity with which they are built up is an expression of some inflexibility of constitution which has barred them from further evolution.

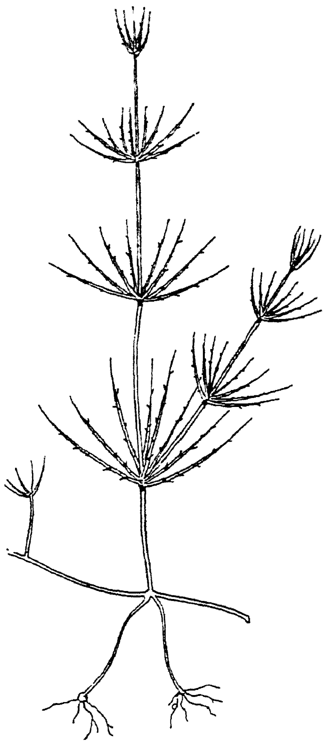

FIG. 331. *Chara*, THE STONEWORT

THE DIATOMS

Among unicellular algae the *Diatoms* are the most peculiar and the most important. Their colour is usually a golden brown and this is

due to the presence of a brown pigment, *fucoxanthin*, in addition to the normal chlorophyll. What part this additional pigment plays we do not know. The chief peculiarity of the diatoms is that their cell-walls are impregnated with a deposit of silica or flint. This completely resists decay, so that, when the plant dies and rots away, or is eaten and digested, a delicate silica shell remains. Where diatoms have lived abundantly for long periods of time, as they often do in peaty waters, the deposits of the shells of many generations may reach considerable thickness. Such deposits are found in some moors in Scotland and Scandinavia and are known as *siliceous earth* or *kieselguhr*. They are of commercial importance as a fine polishing material and as an absorbent for nitroglycerine in the manufacture of dynamite.

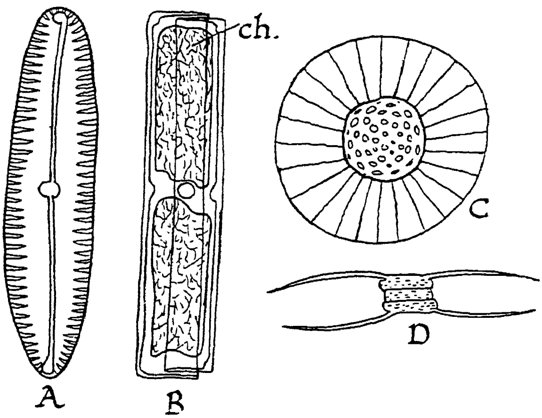

FIG. 332. TYPES OF DIATOM

A, *Navicula* seen from above. B, *Navicula* seen from the side, showing the two halves of the shell, the one fitting into the other; *ch*, chloroplast. C, *Planktoniella*, a floating form with a fringe. D, *Chaetoceras*, a floating form with spines.

Diatoms are very numerous in species and these show great variety in shape. A common form in fresh water, *Navicula*, has the shape of a little boat or date-box. The date-box illustrates very well the plant's structure; for the cell-wall is divided into two halves, or valves, one of which fits over the other as does the lid over the box. The silica shell is elaborately sculptured with radiating lines and dots, and the beauty and fineness of this marking have made these little plants popular among amateur microscopists. Such boat-shaped forms commonly lie on the surface of the mud in still or gently moving water, moving about in a curious creeping fashion which seems to be due to the action of strands of slime protruded through slits in the shell. There are also forms which live attached to other water plants. A sort of colonial existence is achieved by diatoms in which many cells are attached to each other in bands, ribbons, zigzags, or little branched trees. There is, however, in these colonies no sort of integration, but only a superficial gluing together of a number of cells.

In the sea, and in deep lakes, diatoms are extremely abundant in

the surface waters. Here the shape is usually disk-like, a form more suited to floating. Slender spikes or hairs of silica may further increase the resistance to sinking. Especially in the sea, the numbers of diatoms shows a very marked *periodicity*. In early spring, and again in autumn, they may be so abundant as to tinge the water with their brownish colour; in summer and winter they are fewer. A great many external conditions play a part in promoting this climax of population number—light, temperature, and the amount in the sea-water of certain scarce minerals such as phosphates may be mentioned among the factors. The periodic increase in diatom numbers has far-reaching consequences, for diatoms are among the basal foods of marine fishes.

Marine diatoms are not alone in showing such periodic development. Green algae of the fresh waters and another group, the blue-green algae, often vegetate conspicuously in early spring. The old term *Flos-aquae* was applied to the 'flowering' of lakes, when the surface waters team profusely with algoid organisms usually of a greenish colour. It was described by Pliny, who observed it on Lake Bolsena, and it has often been described since. It is well known on Lake Como, turning almost the whole surface of the lake for several calm days into a greenish soup. It is a case of overbalanced reproductivity, induced by unusually favourable external conditions. In a recent Como case the organism was an alga called *Microcystis aeruginosa*. The over-population in a sheltered area may cure itself by using up the oxygen in the water and producing too much carbon dioxide. The plants begin to die off and bacteria begin to abound. Sometimes the state of the water in the 'flowering pond' or 'breaking mere' is so bad that fishes and other animals are asphyxiated. The phenomenon often occurs on a small scale in aquaria.

The reproduction of the diatoms is of great interest. They usually multiply by fission; each new half retains one of the original shells and fits a new shell within it. Now it will be clear that the series which descend from internal shells will progressively diminish in size. Ultimately there comes a time when sexual reproduction takes place by the fusion of two individuals which quit their shells. This process of fusion is something like the conjugation of *Spirogyra*, and it is possible that the diatoms are distant and peculiar descendants of a Spirogyra-like stock. From the product of fusion there arises—usually after rather complicated events—a new and larger individual which builds up fresh shells. Here we have an instance of sexual reproduction where the rejuvenating effects are made visible to us. A race growing smaller through generation after generation of asexual multiplication is given a fresh start, reaching at one step its maximum level of size.

Like the Charas, the Diatoms have given rise to no higher forms. Admirably adapted to their mode of life, eminently successful in their proper station, their rigidity of structure has not proved capable of change to anything new.

The Brown Seaweeds: Phaeophyceae

The green algae, though a large and, especially to the botanist, important group, are but a small part of their class, nor have they attained to any great dimensions or complexity. For the most part they inhabit fresh waters, and it is in the sea that the algal stock appears to fullest advantage; partly perhaps because the sea is its ancestral home, partly, as we have suggested, because the most successful freshwater algae have ceased to be algae. In the sea the green algae are relatively unimportant and the great bulk of seaweeds belong to two other groups. In our northern seas the best represented are the **Phaeophyceae, or brown seaweeds.**

We need only note in passing that in this group too there are simple and inconspicuous forms, unicellular and ciliate, filamentous and branched, very much like their green cousins. Of the filamentous forms the brown hairy tufts of *Ectocarpus* may often be found in rock pools growing attached to other seaweeds. But it is the larger brown seaweeds which chiefly hold our interest as showing something new in form and structure and size. They are plants of rocky coasts. Such large weeds, it seems, cannot live properly floating free and unattached. Inshore they would be dashed to pieces on the rocks if washed about by the waves. In the Open Sea they would doubtless tangle up so completely as to make proper absorption of light impossible. The Sargasso Sea, it is true, has an immense floating population, consisting chiefly of two brown seaweeds; but it is rather a cemetery than a meadow, for most, if not all, of the weeds have been washed from their original home on the shores of the Gulf of Mexico by ocean currents, to gather in a mass continually dying and decaying and continually renewed. On sandy coasts the tide limits are marked by a line of wrack, which crackles beneath our feet as we walk over it just because it is dead and dry. One curious exception has been noted on the shores of the Baltic, where a species of wrack has been found growing in loose sand and mud. But each frond is anchored to the shell of a mussel, and on this the seaweed finds a precarious hold in an unstable world.

The large brown seaweeds for the most part fall within the two great families of the **wracks** (*Fucaceae*) and **tangles** or **kelps** (*Laminariaceae*); there are several smaller groups.

The wracks are typically plants of the rocky shores of temperate

seas, and they tend to occupy the higher zones of the shore, many of them living between the tides, completely submerged at high water and exposed at low. One small species, *Pelvetia canaliculata*, grows at or above high-water mark. 'So patient is this species of drought that it may almost be considered amphibious. It makes its appearance at or above high water where it can only be reached by the waves at the highest tides. Under these circumstances, in calm weather, the plants must often remain dry for days together, and in such cases must be quite dried up; yet when again covered by the tide they will imbibe moisture, and to all appearance recover their vitality and growth.' And the same old authority on seaweeds adds: 'The present species, *though it would rather die* than live at a distance from the briny wave, yet is usually intolerant of more than a good bathe once or twice a day.' And so it lives on exposed rocks in company with those most drought-resisting of land plants, the lichens.

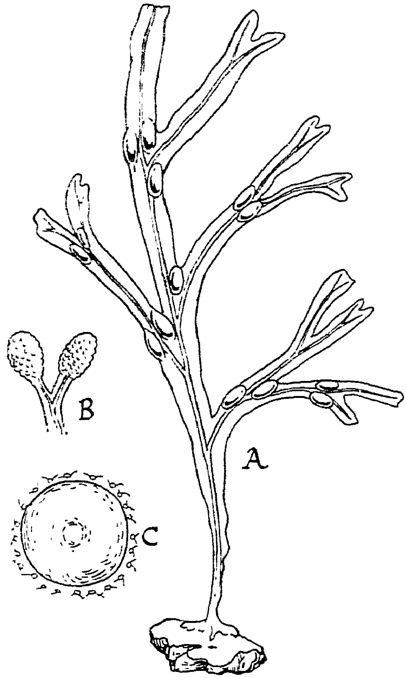

FIG. 333. THE BLADDER-WRACK (*Fucus vesiculosus*)

A, a small plant; B, swollen reproductive tips of thallus; C, egg-cell surrounded by sperm-cells.

A more familiar example is the bladder-wrack (*Fucus vesiculosus*), so called from the rounded, air-filled swellings which burst with a pop underfoot. Its fronds may reach a length of more than two feet. Its lower end is a flat rounded sucker or holdfast. Cells on the lower side of this anchor are so closely pressed into every minute rock crevice that it is easier to break the stalk than to pull it loose. A short stalk expands above into the flat frond, or thallus, an inch or so broad, and bearing a prominent midrib. This frond branches by forking repeatedly, thus forming a very considerable, flat, absorbing surface. At points where forking occurs the air-bladders are to be found in pairs. They may help to keep the plant floating in the water, but they are not found in all species of wrack; the equally common serrated wrack lacks them.

Despite its thickened midrib the whole plant is limp, and it is slimy

to the touch from exuded mucilage. Its limpness is a better protection against its chief danger, the battering of the waves, than the greatest rigidity. A woody shrub, if such could grow in the wave zone, would soon be reduced to fragments. The swaying meadows of the wrack, the flow of water over them further eased by their slime, escape unharmed, save for chance plants torn loose in the worst storms. The slipperiness of the plants may also help to keep them from becoming entangled; one wrack can lash another without doing much damage. For some hours these aquatic plants are exposed daily to the dry air, yet the water-retaining properties of the mucilage help to keep the plant from drying up.

The wracks start their development from a single cell, the fertilized egg-cell. This fixes itself to the rock, grows, divides, and becomes a little filament. At the apex this broadens and thickens, cell-divisions occurring in different planes, to form the beginnings of a thallus. The rest of the development consists of an increase in size, the formation of branches, and the differentiation of tissues which produces the midrib. A peculiar feature of the growth of plants in general may be illustrated here. After the very first stages of development the production of new tissue takes place predominantly at the apex or, as it is called for this reason, the **growing-point.** Indeed in *Fucus*, and in most plants up to and including the ferns, the growth of the whole plant is dominated by the activity of a single cell at the tip of each branch. This cell, as it increases in size, cuts off daughter-cells by walls set, in Fucus, in the direction of four sides of a cube. The daughter-cells grow, divide, and change their form, giving rise to the mature tissues; and, throughout life, the apical cell continues to divide to supply this, the sole material of development. Branching takes place by a daughter growing to equal the mother and setting up as a new apical cell on its own.

The wracks have a cellular structure, but show a great advance over the green algae. In these there is as a rule little difference in form or function between the different cells of filament or thallus, but in the wracks the cells are very varied in size and appearance. Those to the outside are small, equal-sided, and closely massed together; further in they become larger. In the centre and especially in the midribs the cells are long and form an apparently tangled mass of filaments, loosely woven together. These long cells and filaments run with the length of the plant, and they probably help to conduct food-substances from one region to another, besides giving the plant a fibrous strength. It is in the outer cells that the chloroplasts are most densely packed; the pigments are massed on the surface where they can best absorb light. The brown seaweeds contain abundant chlorophyll and, in addition, so much of the brown fucoxanthin as to mask the pure green colour.

Internally, then, the wrack follows the cellular plan of construction established in simpler forms. It shows how a large marine plant may be built up with cells as units. It marks a great advance, for it shows us the cellular bricks very much varied in their form; and this change in form goes hand in hand with change of function. Small cells packed with pigment assimilate carbon dioxide; long cellular filaments conduct and strengthen; cells of intermediate types serve as the matrix which binds all together.

In its external form Fucus hints at root, stem, and leaf. This distinction is yet more marked in other genera, e.g. *Sargassum*, the typical weed of the Sargasso Sea. Its resemblance to a flowering plant is nearly perfect, for there are sharply defined twigs, leaves, and even little round bladders aping berries. Yet in a wrack the distinction between leaf, stem, and holdfast is never sharp as in the flowering plant, and there is no diversity in internal structure. There is an underlying uniformity throughout the body, which is sometimes rounded to a stem-like, sometimes flattened to a leaf-like, organ. The external construction is **thalloid**, and has not reached the perfection of the **leaf-stem** plan of the higher plants.

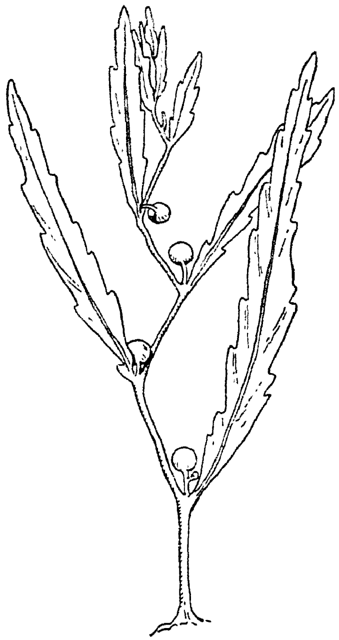

FIG. 334. SMALL PLANT OF *Sargassum*, THE GULF-WEED OF THE SARGASSO SEA

How do the wracks reproduce? Walking along the shore in spring we may often see the tips of fronds, exposed by the receding tide, covered with olive-green or orange mucus. Examination will show that the tips bear raised, rather thickened, patches, with a roughened or pitted surface. These patches contain numerous little flask-shaped pouches opening outwards by microscopic punctures. If a patch is cut across with a knife, the pouches can be seen with the naked eye. They contain sexual reproductive organs. These take the form of delicate bladders inside which are formed either eight large, round egg-cells or very numerous minute bi-ciliate sperms.

On our British shores, where there are marked tides, the bladders of eggs and sperms leave their cavities at low tide, squeezed out by the drying thallus. While the tide is out they lie on the surface of the

thallus-tips in coloured mucus. With the rising tide they are submerged, and the bladders, which still contain the reproductive cells, burst, liberating their contents. Multitudes of sperms encircle each egg, setting it in rotation with the vigour of their lashing movements. After a short time one enters and fusion occurs; the others immediately swim off, repelled by some obscure change in the chemistry of the egg-cell at the moment of fertilization. The zygote or fertilized egg-cell settles down and begins at once to develop. There is no resting stage, and in the sea there is indeed no danger of the water-supply drying up.

The wracks have only sexual reproduction and it is of an advanced type. The sperms are very minute and very active. An egg-cell has about 5,000 times the bulk of the sperm, and is passive and well nourished. It might seem that in the waters of the sea the chances of sperm finding egg-cell would be remote. But the two are produced near each other in immense numbers; they get into the water as the tide rises, and the eggs are immersed in a regular soup of sperms. That fertilization occurs often is proved by the thick meadows of wracks which everywhere clothe the rocks.

A remarkable feature in the habits of these plants is the way in which they grow in definite zones along the shore. About high-water mark grows the smallest of them, the *Pelvetia* we have already mentioned. Just below it is a band of the wrack *Fucus spiralis*, and below this comes the bladder-wrack (*Fucus vesiculosus*). This last, however, may be absent on very exposed stretches of coast; it avoids the worst onslaughts of the waves, but may be found in the shelter of large rocks. Still lower comes a very large and conspicuous species, *Ascophyllum nodosum*, consisting of branching stem-like portions with very little in the way of leafy expansion, but with specially large bladders. And finally, just uncovered at low tide, is the serrated wrack (*Fucus serratus*). At low tide the succession from below upwards of the different species on a shelving rock may be very striking. Why the different species should be so sharply limited in their occurrence is not fully known. The determining factors include the different powers of withstanding drought, the influence of fresh rain-water, and the action of waves. It is of interest that the time of exposure to dry air required to bring about the proper liberation of the gametes varies with the position occupied by the different species.

The second great group of brown seaweeds, the **kelps** (*Laminariaceae*), is not quite so familiar, for its members inhabit still deeper water and are not uncovered by the tide. But sometimes a kelp is torn loose and its great leathery frond, a yard or more long, is cast up on the shore. Wading in the water at low tide we may reach for them in the ebb of the waves, and try in vain to tear them from their

hold. In the hollow of the waves the tips of a forest of fronds come into view on the surface, to be submerged a moment later in the swell. Round British coasts the reefs are covered with these great seaweeds, and from them (and from some of the wracks) the kelp-gatherers of the Hebrides, the Aran Isles, and the coasts of Brittany gathered the material for their kilns.

The kelps of our coasts are not numerous in species, but three are common. All have a strong stalk a foot or two long and thumb-thick. The stalk is fixed by a massive branching holdfast; it broadens above into a great frond, a yard or two long, and as much as a foot broad, thick and leathery. The single broad frond is not so well suited to withstand wave action as the forked wracks, but the kelp is almost always covered by water. One species, *Laminaria digitata*, which lives further inshore than the others, has the frond split into segments as it grows old, chiefly by external forces. A second common species is *Laminaria saccharina*, with undivided corrugated fronds. A third, *Alaria esculenta*, has a midrib and reaches the greatest size of our native sorts. Its stalks are still sometimes eaten, though more as a condiment than as a food. The stems of the kelps are sometimes sold by fisherwives in Scotland for infants to cut their teeth on.

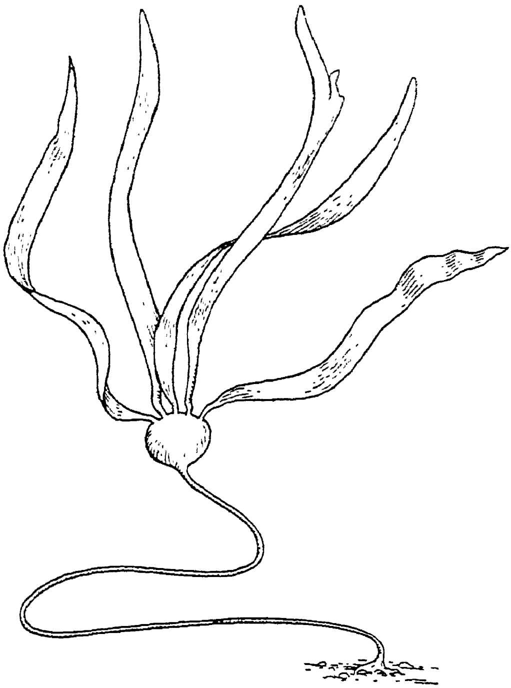

FIG. 335. *Nereocystis*, A GIANT KELP OF THE PACIFIC

Like the wracks, the kelps are seaweeds of the colder seas. North and south on the Atlantic shores of Europe and America they are at home. In Pacific waters some enormous and otherwise remarkable forms occur. *Lessonia* has a stout erect stem as thick as a man's arm, and bearing above a tuft of branching fronds, the whole rather like a palm tree and as much as twelve feet high. On the west coast

of America grows the giant kelp *Nereocystis*. A long slender stem rises from the bottom, where it is anchored, and is floated to the surface by an immense bladder a foot in diameter. From this springs a divided frond not unlike that of *Laminaria digitata*, but as much as seventy feet long. The total length of the plant may be fifty yards. But the greatest of all seaweeds is *Macrocystis*, which grows around Cape Horn and far up the Pacific coast From a depth of fifty feet or more a long slender stem of the thickness of a clothes-line slants up to the surface. At regular intervals it bears fronds four to five feet long, each with a bladder at its base. In the surface waters the stem stretches horizontally, buoyed up by the bladders with their pendent fronds. The total length may approach a hundred yards. Only the tallest trees exceed this enormous size. Darwin, who saw this kelp during his voyage on the *Beagle*, remarks that ' the beds of this seaweed, even when of no great depth, make excellent natural floating breakwaters. It is quite curious to see, in an exposed harbour, how soon the waves from the open sea, as they travel through the straggling stems, sink in height and pass into smooth water.'

A curious property of the kelps, shared by no other plants to like extent, is their capacity for accumulating iodine from the minute traces present in the sea-water. The kelp-burners acquired a spurious healthy brown hue from the effect of its vapours. Before the exploitation of the Chile saltpetre beds, kelp was the chief source of iodine. Kelp also yielded soda and potash for glass-making, and the ash was, too, a valuable artificial fertilizer for the farm.

Internally the kelps have a structure similar to that of the wracks, though the process of cell-differentiation has gone further, notably in the production of very advanced conducting cell-filaments, which seem to foreshadow the conducting strands of the bast of flowering plants.

Alternation of Generations

In the reproduction of the kelps we meet with a new and important development. On the surfaces of the fronds there grow, usually in winter, inconspicuous patches or **sori** (sing. *sorus*) of **sporangia**, that is, of cells in which spores are formed. The sporangia are interspersed with sterile and, perhaps, protective, club-like hairs. Many zoöspores are formed in each sporangium. This reproduction is asexual. When the zoöspores are liberated and germinate, which they do, as is usual in the sea, without any period of rest, they do not grow into a new Laminaria plant. They produce only minute filaments a few cells long and slightly branched. On these filaments are formed either egg-cells or sperm-cells. The motile sperm-cells fertilize the passive egg-cells, and the zygote grows into a Laminaria. Lami-

naria thus has *both* sexual and asexual reproduction and the two kinds alternate regularly. But more striking is the fact that each kind is effected by quite a different plant. In the life-cycle a sexual plant or **gametophyte** alternates with an asexual plant or **sporophyte,** and this state of affairs is known as an **alternation of generations.** The arrangement does not arise suddenly as a character of Laminaria. It is indicated in the details of the life-history of many green algae, and it is seen in other and simpler forms of brown seaweeds. The process in Laminaria is so sharply defined and so remarkable, on

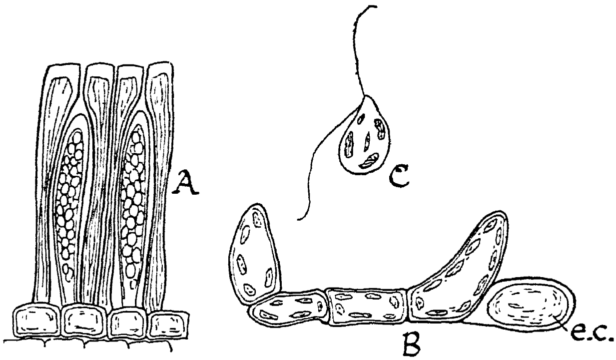

FIG. 336. REPRODUCTION OF *Laminaria*
A, sporangia set on the surface of the thallus between protective cells. B, the minute sexual plant; *ec*, egg-cell. C, sperm-cell.

account of the great difference in the size of the two generations, that this seaweed is a convenient introduction to a kind of life-cycle normal in all the higher plants.

It is necessary here to refer briefly to the detailed nuclear events which accompany the process of reproduction and which have been dealt with in the animal part of this book. The dividing nucleus shows within it the existence of a number of threads of specialized protoplasm called **chromosomes** which split longitudinally, each into two halves, one going to each daughter-nucleus. The number of chromosomes is constant for any particular species. With the sexual fusion the number of chromosomes in the zygote is doubled, and the double number is maintained in all the cells of an animal until the sex-cells of the new generation are formed: then a unique type of division, *sending whole instead of half chromosomes to each daughter-cell,* brings back the single or half or **haploid** number. This is what happens in Fucus, but it is a very unusual arrangement in plants. In Laminaria this **reduction-division** takes place just before the zoöspores

are formed. So it comes about that the cells of the minute sexual generation are haploid, and all those of the asexual generation are **diploid.** This is the normal chromosome cycle in plants—doubling of chromosome number at sexual fusion, diploid number through the asexual generation, halving of chromosome number at spore formation, haploid number throughout the sexual generation. The necessity for reducing the number of chromosomes is not the reason for the alternation of generations—higher animals have no alternation and do very well, as does indeed the plant Fucus. But the chromosome life-history has in the majority of plants been fitted into the regular alternation of sexual and asexual phases in a very neat way. And, with few exceptions, both follow this pattern in all plants higher than the algae.

All this does not answer the question which may occur to us: What is the meaning to the plant of the regular recurrence of two different kinds of reproduction? So far as we could we have already given an answer. Asexual reproduction, independent of the hazards involved in the meeting of two cells for fertilization, is admirably suited to secure rapid multiplication; and as the reproductive cells are free to move, or be moved, the possibility of dispersal is linked with the process of reproduction. Sexual reproduction, on the other hand, cannot be so certain of unlimited success. It provides for one of the profound and obscure necessities of living matter for some sort of periodical regeneration. As to the nature of this we are very much in the dark. There is another aspect of sexual reproduction of less direct importance to the individual organism, but perhaps of governing importance in the history of evolution. When sperm-cell fertilizes egg-cell the hereditary characters of two different individuals are combined. Through the variation of individuals evolution has taken place. The sexual process brings it about that such variations as crop up do not remain, as it were, isolated; those of one individual may be mixed with those of another. Variation may be added to or even multiplied by variation, and, in this, the evolutionary process has certainly been enormously accelerated. The effect does not stop at this. When the reduction-division takes place the hereditary characters of the two parents are sorted out at random, and in the offspring of subsequent sexual reproduction all sorts of new combinations of characters may appear. All this matter is explained more fully in another place. Here we wish simply to summarize the effects which sexual reproduction is able to produce.

Given the two sets of advantages of the two kinds of reproduction, it is clear that an ordered alternation of the two kinds will be a happier arrangement than one that is haphazard; and this orderly arrangement is secured in the plant's alternation of generations. It is indeed

fascinating to contemplate how, in this simple and orderly succession of two phases in the single life-cycle, so many intricate and complex events in the nucleus, so many important considerations in the welfare of the individual and in the progress of the race have been cared for.

And finally, we might ask how it is that in the higher animal, as successful as the plant is in its line, this type of life-cycle is entirely absent. The answer is that in a free-moving organism the process of sexual reproduction is less hazardous, for mate can seek mate consciously or unconsciously. And in the free-moving animal dispersal is always possible throughout life. The sexual process here is more certain and the need for a dispersive phase is gone. The higher animal does not require asexual reproduction.

The Red Seaweeds: Rhodophyceae

The third great group of algae is that of the red seaweeds. This includes many of the most elegant and beautiful of the lower plants. Red seaweeds are at their best in warmer seas than our British, and in rather deep water; but our rock pools offer a large variety. In size they are much inferior to their brown cousins—weeds a foot in length are exceptional—but in form they are even more varied. There are delicate filamentous forms growing like little tufts of deep crimson hair, often on other seaweeds, as is the case with *Callithamnion* and with the coarser *Polysiphonia*, one species of which is always to be found on Ascophyllum. Others form stout forked rods, e.g. *Furcellaria*. Most elegant are the ribbed and branching plumes of *Ptilota*, *Delesseria*, and others. Antlered shrubby growths of *Chondrus*, the edible carragheen or Irish moss, may cover considerable tracts of rock. *Gigartina*, another shrubby form, often grows with the last and is not always easy to tell from it, though its channelled frond and warty surface help. The deep red, broad, rounded, cartilaginous fronds of *Dilsea*, and the more divided purple thallus of *Rhodymenia*, are examples of simple fronded types. Most remarkable of all are the species of *Corallina*, hard and stony owing to encrustations of limestone, and not unlike the true corals in their pink branching tufts. There are also encrusted forms, *Lithothamnion*, and others, which clothe large areas of rock with a pink petrified crust impossible to remove. These coralline and encrusted forms are specially common and well developed on tropical coasts where the action of breakers makes it impossible for any but the hardiest and best-protected weeds to survive. But all that we have mentioned, and many others, may be found on the rocks of British and similar coasts, or in rock pools, or washed up by the waves. Their hue varies as much as their form. Some are brilliant crimson, like *Delesseria*, some dull like *Dilsea*; some

have a brown-red tinge as in *Polysiphonia*, others are more purple, as in *Rhodymenia*. There are species which show no trace of the red colour, e.g. *Laurentia*, the pepper-dulse, which is olive green; this holds for the relatively few representatives of the group which live in fresh water. The colour of the red seaweeds is in fact due to the presence of at least three different pigments. There is chlorophyll always present, its green masked by other and brighter colours. There is **phycoerythrin** which is red, and **phycocyanin** which is blue. According to the relative amounts of the three pigments, the particular plant has its own special hue. It will be seen that the colour may range from nearly pure green, through the brightest reds, to purples. We have in the case of the red seaweeds a clue to the meaning of the peculiar pigmentation. They live under water and, though the most familiar members are of course those which live high on the shore, they are most richly developed in warmer seas at greater depths. Even in the rock pools it may frequently be observed that the red seaweeds favour the shaded side and the crannies. Now light transmitted through water is by no means so 'white' as that falling on the surface. Even the water in a bath looks green, because of the absorption of the red rays of the spectrum; at a depth of several yards the light is very blue indeed. Red is complementary to blue, and consequently a red pigment absorbs blue or green light more efficiently than a green one. The red seaweed is therefore fitted for absorbing the blue light which penetrates water. Incidentally, since diffused light, the light of shaded places, is predominantly blue, the red seaweed is also better fitted to live in the shade. The red pigment confers a double fitness on the inhabitant of a depth where the light is dim and blue. But how the red pigment has its action linked to that of the chlorophyll which is also present, and which is no doubt the principal agent in photosynthesis, we do not know.

In structure the red seaweeds are simpler than the wracks, or rather, they are built up on a more primitive plan. The branching filament is their structural unit, and even their outwardly most complex forms are built up by an elaborate weaving together of such filaments. They do not, as in the wracks, form true tissues in which an apical cell, dividing by walls in appropriate directions, gives rise to a closely compacted cell-mass, each unit of which is in intimate and firm connection with all its neighbours. Perhaps we may make the distinction clear if we say that in structure the red seaweed resembles a plait of hair or a web of cloth, and the wrack a honeycomb. The woven filamentous type of construction leads to quite large plants, firm in texture. Yet it appears that it is incapable of giving such size, strength, and, above all, differentiation as the true tissue structure. It is another blind alley fully explored by the red seaweeds and leading no further.

In reproduction the red seaweeds may be extraordinarily complex. The simplest case is exhibited by *Nemalion*, a forked species of soft consistency, and by *Batrachospermum*, one of the few freshwater types. These plants are sexual and produce egg-cells and **spermatia,** male cells peculiar in being without cilia. The egg-cells lie in a flask-shaped cell with a long receptive hair with which the spermatium drifting in the water fuses. The fertilized egg-cell grows out into a bunch of little branches, in the apical cells of which asexual spores are formed. These spores also lack cilia. In fact throughout the red seaweeds there are no actively motile reproductive cells. Here we have an **alternation of generations** in which the asexual phase is small and parasitic on its sexual parent. In many species the branches which grow from the zygote are long. They grow over the parent and, here and there, fuse with one of its cells. This fusion is purely nutritive; the parasitic asexual generation has beco ne larger and provides better for its nutrition; it forms later many bunches of spore-producing cells at scattered points of the sexual plant. In *Polysiphonia* and many others the asexual spores do not give rise to a new sexual plant. From them there develops a plant exactly like the sexual one, but producing asexual spores in groups of four; these in turn develop into sexual plants. Here we have an alternation of *three* generations, sexual, parasitic asexual, and free-living asexual. The first and last are exactly similar in external appearance. What significance is to be attached to this type of life-history it is difficult to see. We gain the impression that reproduction in the red seaweeds is in an experimental condition or has strayed into a needless complexity. At all events, it is the simpler plan of *Laminaria* which has become standardized in the higher land plants and seems not only to meet all requirements, but also to be capable of modification to suit fresh conditions.

Seaweeds as Food

Several red seaweeds are of considerable economic importance. From carragheen (*Chondrus* and also *Gigartina*) is made a suave jelly used in the preparation of throat pastilles. Carragheen is also used to make a gelatinous food for invalids. Various Japanese species, e.g. *Gelidium corneum*, yield the gelatinous material **agar-agar.** This is sometimes used in cookery, and is of great importance in preparing nutrient jellies for bacteriological work. Its jelly keeps firm at much higher temperatures than ordinary gelatine, so that it can be used for cultivating bacteria at blood-heat. Agar also gives a striking example of the water-absorbing capacity of algal material, for it forms a jelly with an agar content of only 2 per cent which is nevertheless perfectly firm.

Many seaweeds have been or are used as a food or as a condiment.

The pepper-dulse (*Laurentia*) has a distinct and pleasant spicy flavour. The 'birds' nests' consumed by the Chinese are in their perfect form due to the mucus of the sea-swift's salivary juice, but this may be eked out with gelatinous seaweed.

Long ago, in college days in Edinburgh, we used to hear the fisher-wives from Musselburgh making the 'closes' ring with their penetrating cry: 'Wha 'll buy my dulse and tang, dulse and tang?' They were hawking the fronds of dulse (*Rhodymenia palmata*) and other seaweeds, which were believed to be health-giving and disease-averting. Even to-day the Aberdeen fisherwives cry 'Caller dulse' in the streets.

Modern research has justified this belief by proving that iodine, which is well represented in some of the seaweeds, is a useful, indeed 'absolutely essential,' constituent of the food of man and beast. That iodine works against goitre and allied deficiency-disorders has long been known more or less vaguely, now the fact is precise and insistent. In our youth it was customary to give invalids, especially ailing children, dishes of carragheen, which contains in its gelatinous substance a good percentage of iodine.

Even to-day we see sailor-men, who look defiant of all the ills that flesh is heir to, eating with evident gusto the fronds of dulse which they have bought at the fish-market. After a longish voyage the dulse probably supplies some needed vitamin, as well as iodine. Perhaps Nebuchadnezzar, who had for a while to eat grass like an ox, was not so far out dietetically. In any case, he got better!

It has become quite clear that the infinitely little in the way of inorganic constituents (and we may include some form of iodine under this heading) may be just as indispensable as an infinitely little quantity of some organic vitamin.

Living matter is a chemical firm, usually, if not always, with 'Mind' in the head office, as potent as it is inaccessible. The visible members of the firm are not all of the same importance, for no one will credit a carbohydrate or a fat with the dignity of a protein. But the point is that while none of them is essentially important by itself, the efficiency of the firm is due to the way in which the various members co-operate, working into one another's hands. The visible members of the life firm are proteins, carbohydrates, fats, water, and salts, besides some rather elusive members whose department is headed 'enzymes,' or, in old-fashioned labelling, 'ferments.'

If we *isolate* the visible members of the firm they are often unimpressive (though they may suddenly exhibit unsuspected powers of exploding, advertising, thieving, maddening, poisoning); but it is as a firm that they are so formidable. Life is largely an *entente cordiale* based on a balanced synergy of powers.

But we must go further and recognize that in the materials on which

the essential living matter or protoplasm works within the body there has to be a sustained 'balance.' The organisms that could not balance their accounts have proved failures, or, since Nature is sometimes good-humoured as well as stringent, they have subsided into quaint, half-dead survivors, for whom life cannot be much worth living.

Iodine is widely distributed, in very small quantities, in minerals, soils, seas, rivers, and the dust of the air. It is common in plants, but seaweeds have much more than freshwater plants, and the latter are richer than terrestrial plants. As long ago as 1819, Fyfe of Edinburgh demonstrated the presence of iodine in sponges; that was seven years after the discovery of the element itself by Courtois, a nitre manufacturer of Paris. But its occurrence is now known to be widespread in the animal body, from freshwater crayfish and snails to mammals, where it is detectable in blood and milk, but particularly in the thyroid gland, which lies beside the voice-box or larynx.

Crofters near the coast in the Highlands and elsewhere have often proved the value of manuring their little fields with seaweed; and while other constituents are, of course, most important, it seems likely that the iodine, relatively abundant in the seaweed, counts for something. In any case, there are some precise experiments that point to the conclusion that a controlled dosage with iodine favours the growth of certain plants, and also renders their chemical routine more effective. But there is need for more experimentation along this line.

The sailor chewing dulse is directly introducing more potassium iodide into his food-canal, and thus into his blood; but the net result will be affected by the regulating thyroid gland, which produces the influential iodine-containing chemical messenger or *hormone*, called **thyroxin.** This thyroid hormone, thyroxin, is essential for the continued health of body and mind; and the organ must be regarded as the controller of the iodine exchanges in the body.

It is plain, however, that a controller's function will not avail if there is an initial deficiency in the material to be controlled. So we come back to the importance of an adequate supply of iodine in the food.

One of the most repulsive and humiliating of human diseases is goitre, which is marked by an enlargement and pathological condition of the thyroid gland, and by associated bad health. The goitrous gland, once disagreeably common in some Alpine resorts, is represented by Derbyshire neck and allied disorders in England. The enlargement of the thyroid is accompanied by a reduction in its iodine content, and the whole body suffers. This reduction in the iodine content and in the health-maintaining, iodine-containing hormone may be due to other factors, but *the main factor is a deficiency in the iodine intake.* While confined animals in certain regions suffer from goitre, their wild relatives that get 'salt-licks' of iodine remain in vigour.

As regards man, it may be said that 'in the vast majority of cases administration of iodine arrests the growth of the goitrous glands and reduces their size.' This seems to us an exhilarating scientific statement. As Comte said: *Savoir pour prévoir afin de pouvoir* (Knowledge is foresight and foresight is power).

And if it be asked how man is to get his 'salt-licks,' we suppose that the answer is that he must try to secure a *mixed natural diet*, like his father before him. One of the dangers of civilized life is that people become accustomed to very artificial food bereft by overcooking of its health-giving vitamins.

Fossil Algae

In studying groups of plants we often find, as we shall see later, that light is thrown on their origin and nature by fossil relatives. If we had abundant fossil seaweeds we should perhaps know, what is still a mystery, from what algal stock the higher plants are descended. Unfortunately seaweeds do not generally lend themselves to preservation, their material is soft and perishable, and in the hungry sea not much is left to the influence of time and the growing rocks. Of the algae only those peculiar forms, chiefly red seaweeds, which are encrusted with lime are found to any great extent as fossils, and rock-formers, and the very qualities which make this possible make them a notable example of a peculiar evolutionary tendency. They afford an illustration, from among plants, of life overreaching itself. Many calcareous algae live in conditions of great difficulty, and become so densely packed with limestone that it is difficult to believe that they are alive at all. They might be called vegetable corals, and they also resemble corals in having added considerably to the solid earth. The calcareous salts they have filched from the sea have been returned to the solid earth, whence the rivers dissolved them. In other words, many calcareous seaweeds have formed in past ages very substantial beds of limestone. But it is only to a very slight extent that they are doing this to-day.

Dr. Julius Pia, of Vienna, who has written a book on *Plants as Rock-builders*, divides the calcareous algae into the encrusting, the tuberous, and the arborescent. The rocky sides of a shore pool often show a fine pinkish colour, which is due to a firm crust of a very common calcareous alga called *Melobesia*. It may also be seen painting long stretches of vertical cliff and rising considerably above the low tide-mark. In some sea caves Melobesia gives a striking colour to the water-washed walls. But some of the encrusting types are less close-fitting than Melobesia. Thus there are species of *Lithothamnion* which are covered with rounded knobs, and there are species of *Litho-*

phyllum that show leaf-like ridges, reminding one of a foliaceous lichen. No doubt they are successful; they cover large expanses of rock, besides loose stones and shells; they thrive under the battery of the breakers and the rush of strong currents. All they ask for is light, water, and foothold. Like ordinary plants, they use the light to build up air, water, and salts into carbon-compounds; and thus they are not found below a few dozen fathoms.

But our point is that by their constitution and by their conditions of life they are forced to smother themselves in limestone—so much so that vitality is reduced to a minimum. They have a few analogues in fresh waters that are very rich in limestone.

Some of the marine encrustations are weathered off by the frost and by the stones with which the waves scour the rocks, and particular kinds of calcareous sand are formed in this way. In other cases, however, the encrustation clings closely and becomes thicker and thicker. It is added to above as it dies away below, and thus substantial masses may be gradually built up. In some cases they might even be called fringing reefs.

The tuberous calcareous algae are free growths, often with a stone or shell as centre. When cut across they show concentric zones, the denser, narrower lines representing the unproductive winter; and a counting of the zones proves that some may live for a score of years. They are strange spheroidal or flattened bodies, rarely exceeding a few inches in diameter. Some forms found in lakes are called 'water-biscuits.' In slow-flowing reaches of rivers much bigger 'lime-balls' are sometimes formed, as in the Rhine near Constance. The surface of these tuberous algae may be smooth, wrinkled, or even rugose. What strange forms of life they are; and our point is that it looks as if the conquered inorganic was proving almost too much for the victorious organic.

The third group of calcareous algae is that of the free-growing or arborescent corallines. Everywhere in the shore pools there is the pinkish *Corallina officinalis*, which turns white when it dies. The common Corallina is like a miniature stiffly-branched tree, and is often mistaken for an animal colony or zoöphyte. But there is great variety of architecture in this group, for some are jointed rods and others are like Indian clubs, some are like umbrellas turned inside out and others are spheres mounted on stalks, some suggest the leaflets of a maiden-hair fern and others are like growths of mould exaggerated and petrified, some form networks and others are like little trees. They do not grip the substratum so firmly as the encrusting types do, and are naturally found in quieter waters. When they die there is a slackening of their grip, and they are torn off and pounded into sand.

Many of the calcareous algae are, as we have said, very like animal

corals, and they seem to us to illustrate the danger of an adaptation going too far. Not too far for survival, for that would mean that the adaptation had become a mal-adaptation, but too far to allow of much pulse of life. Just as an accumulation of fat may become too much for a man, so an accumulation of calcium carbonate may become too much for a calcareous alga or for a coral. The deposition of limestone may have, to begin with, something to do with counteracting poisonous waste-products, and it may also be utilized for support and skeleton; but there is a risk involved in organic momentum. The calcareous algae are warnings, for they illustrate life in chains.

The stoneworts, too, are known as fossils from very ancient rocks; but they do not take any great part in rock formation. And there are several very obscure fossils which are important rock-builders, and are sometimes said to be algal remains, though the identification is not always very convincing.

The Algae—A Summary

Among the algae we find some of the simplest of plants. There is little doubt that each of the three great groups arose from unicellular, ciliated, free-swimming forms. We can even trace the story further back to forms in which as yet no cellulose wall had been formed. Still further back they may have had ancestors in common. The many features they all have—above all, the possession of the essential pigment chlorophyll—makes this likely.

But from their origin in the remotest times they have followed three separate and independent lines of evolution. Along these, plan after plan of structure, reproduction, and form has been tried out. In no other division of the plant kingdom do we find so many experiments. And nowhere do we see so clearly stated the great lesson that life is as much experiment as experience. Sometimes, as in *Chara*, some stock has entered a definite blind alley; sometimes, as in the red seaweeds, we may suspect that this is so, and yet not be sure that some further possibility does not lie hidden in the stock. In the green and brown algae, however, we can clearly recognize types of structure and reproduction which point towards the higher plants; from one of these groups almost certainly the higher plants have come.

The green algae, predominantly freshwater plants with the right pigment, are the more likely. Yet the browns have been suggested on account of the very advanced type of internal structure which they possess. Be that as it may, on their own level the algae have produced an infinite variety of fascinating forms, and have peopled the waters of the shore, wherever there is foothold and a sufficiency of light, with meadows as rich as any of those on land.

CHAPTER IV

THE FUNGI

The Grey Moulds: Zygomycetes—Water Moulds and other Oömycetes—Plant diseases—The simpler Fungi: summary—Blue Moulds—The Yeasts—Useful Moulds—Other plant diseases—The larger Ascomycetes—The Rusts and Smuts—Toadstools and Mushrooms.

It is the special attribute of the plant to build up food from carbon dioxide and water, and to do so with the aid of light-energy absorbed by the chlorophyll. Among the flowering plants there are some few which, with a dingy brown yellow or purple hue, possess none of the essential pigment. Such are the broomrapes and the dodder and the bird's-nest orchis. They obtain their food from living plants as parasites, or from dead organic matter as saprophytes. They have fallen from the true way of life—for a plant—and are rather exceptional degenerates. On the same level of organization as the algae, however, there is a very large group devoid of chlorophyll. These are the **fungi.** Although they lack one of the chief characters of the plant, these organisms are not thereby to be regarded as animals. In structure, in reproduction, and in much of their manner of life they are essentially plant-like. They have almost certainly descended from a stock, or perhaps from several stocks, of the algal group. Chance variations have led to loss of chlorophyll, and the opportunities of using the ready-made food available in the abundant decaying matter on a land surface have been seized. Thus the fungi have been led to exploit the possibilities of another way of life.

It is significant that fungi are rare in the sea, are more common in fresh water, and attain their fullest development on land. In the sea, where all dead organic matter is swept up by an immense and hungry population, the opportunity of using such foodstuffs is not present. But when plants and animals die on land their dead remains often accumulate, as we may see on any walk through a pine or beech wood. In this rich medium the fungi and bacteria found and seized their chance. Environment, as affording opportunity, has played its part in evolution as well as the innate changefulness of living things.

The fungi may be classified as follows:

(1) Phycomycetes. The Lower Fungi.
 (*a*) **Zygomycetes.** Grey and Black Moulds.
 (*b*) **Oömycetes.** Water Moulds and Downy Mildews.

(2) Ascomycetes. Blue Moulds, Mildews, Truffles, Cup Fungi.

(3) Basidiomycetes. Rusts, Smuts, Mushrooms, Toadstools, Stinkhorns, Puffballs.

The differences between these classes cannot be easily stated in a brief way, but will become clear in the descriptions which follow.

The Grey Moulds: Zygomycetes

One of the commonest of all fungi is the pin-mould (*Mucor*), which appears rapidly on old damp bread and on jam. It looks like a forest of little glistening white threads standing straight out, for an inch or so, from the surface of the bread, each thread capped by a black pinhead. With the microscope it can be seen that these threads spring from a white felt of much-branched filaments woven in and on the surface of the bread. The plan of structure is that of a filamentous alga and it most closely resembles Vaucheria, for in the filaments are no cross-walls. The wall is not made of ordinary cellulose, but of a substance more like the chitin which forms the stiff covering of insects. It is lined with protoplasm containing numerous minute nuclei and enclosing the usual bulky vacuole filled with watery sap. There are no chloroplasts. Here again is a group of plants—the character is common to all the *Phycomycetes*—built on the hollow tubular plan. Again we find that this plan leads to no great complexity of structure, for these are the simplest of the fungi.

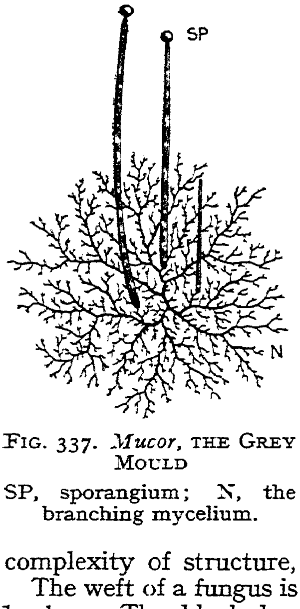

Fig. 337. *Mucor*, the Grey Mould

SP, sporangium; N, the branching mycelium.

The weft of a fungus is called a **mycelium** and the individual threads **hyphae.** The black heads are the asexual reproductive organs or sporangia. The tip of a hypha which has grown towards the light and risen into the air, swells out, and behind it a wall is formed, cutting off its contents from the rest of the filament. It is only in connection with the formation of reproductive organs that cross-walls are found in these fungi. The head continues to swell and the wall pushes into it. The contents are cut up into a large number of minute spores, each of which secretes a wall. A gelatinous substance lying between the spores absorbs moisture, swells and bursts the sporangial wall;

and the spores are liberated in the air. They may float long distances because of their dust-like size. They can withstand drought and can rest before germinating. When they fall on a suitable damp surface they sprout at once, pushing out a slender hypha which, growing and branching, forms a new Mucor plant. That these spores are always present in the air, especially in the dusty air of rooms, is evident from the rapidity with which a piece of damp bread left lying about becomes infected. The bread as it comes from the baker's oven is sterile; it is only when a slice is exposed to the air that infection takes place.

Mucor has also sexual reproduction. Two hyphae approach each other. They touch and their tips are separated from the rest by cross-walls. The touching walls disintegrate and the contents fuse. The resulting **zygospore** becomes covered with a very thick and resistant wall, and rests for a long time before it germinates. It then usually forms at once an asexual sporangium and the spores from this give rise to new Mucor plants. It has been found that this sexual-like fusion can take place only between hyphae belonging to different mycelia or Mucor plants. In fact, all the mycelia of Mucor fall into two classes which we may call A and B. An A hypha cannot unite with an A hypha nor a B with a B. But hyphae of any A mycelium can fuse with those of any B mycelium. There is no obvious difference between the two classes of mycelia except that one grows rather less vigorously than the other. Yet the fact that conjugation is not random shows that we have here an elementary sort of sex-differentiation.

There are many species of Mucor and of related genera, most of which lead inconspicuous lives on dead leaves, dung, and such-like organic débris. Some have taken to a parasitic mode of life and prey on their relatives. One sort, which may sometimes be found on horse-dung, *Pilobolus*, is remarkable because the stalk of the sporangium is swollen into a bladder, which, when ripe, bursts and flings off the whole sporangium into the air to a distance of some inches.

Water Moulds and other Oömycetes

If we throw a dead fly or ant's egg into a dish of tap-, or better, pond-water, we find that in a few days it becomes surrounded with a halo of radiating filaments much like those of *Mucor*. This is *Saprolegnia*, one of the water moulds. Some species of Saprolegnia vegetate in living fish—goldfish and salmon—and cause serious trouble. After its death the fish becomes surrounded by a halo like that on the dead fly. In structure the water moulds are non-cellular, like Mucor. In reproduction they are more advanced. The tips of the hyphae swell

into club-shaped sporangia which liberate many ciliated zoöspores, asexual reproductive bodies dispersing themselves by swimming. Usually later in the life-history the same plant develops rounded swellings containing several ova. These are fertilized not by free sperms, but by male branches which pierce their walls and inject the nuclei necessary for fusion. The oöspores rest before germinating. Here there is no doubt as to the existence of a sexual fusion, though both sexes are formed on the same plant.

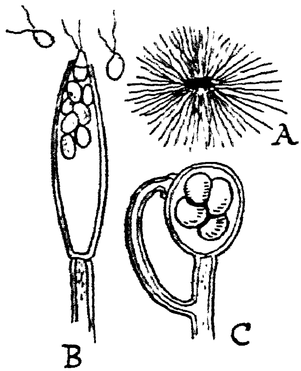

FIG. 338. *Saprolegnia*, THE WATER MOULD

A, dead fly surrounded by mycelium. B, sporangium with escaping ciliate spores. C, sexual reproduction.

Other members of the class are of much greater importance to mankind, for they are responsible for serious plant diseases. Thus *Plasmopara viticola*, the downy mildew, is very destructive to vines in France, Germany, and Austria. More important in our country are *Pythium debaryanum*, which causes 'damping off' of seedlings, and *Phytophthora infestans*, responsible for potato 'blight.' The 'white rust' of cabbages is due to another of these fungi called *Albugo candida*.

Phytophthora lives in the potato leaves and haulms, sending its hyphae through the tissues between the cells. Not only does it draw nourishment from the cells of its host and so impoverish it, but it also secretes a poison or toxin so that the potato leaves wilt, die, and, in cases of severe infection, collapse in a brown and evil-smelling mass. Nourishment of the growing tubers is of course interfered with, and the tubers themselves are infected and damaged. Before the leaf is destroyed the fungus reproduces itself. Hyphae are sent out to the surface through the stomata, and, when in the air, they branch. At this stage the fungus may be seen as a sparse white mould on the leaf. From the tips of the hyphae, swollen sporangia are cut off and broadcast by the wind. If one lights on a potato leaf in damp weather it liberates a number of ciliated zoöspores which shortly settle down, put forth little germ-tubes, penetrate the leaf, and start the disease afresh. Two points are of interest here. The first is that, in forming ciliated zoöspores the fungus betrays its relationship to, and probable origin from, aquatic forms such as Saprolegnia; for it is only in water that zoöspores are really useful. A true land fungus like Mucor never produces them. The second is that, because of the necessity for water for germination, the fungus can only produce

serious infections in wet weather. It is indeed common knowledge that potato blight is most serious in wet seasons. The fungus first appeared in Europe in 1840, probably introduced from America. The bad blight year of 1845 led to the Irish famine with all its immediate misery and political and economic consequences.

Potato blight, like most plant diseases, cannot be cured. But it need not be endured, for it is possible to take measures to prevent its worst ravages. The most effective method of preventing potato blight, vine mildew, and various other diseases is precautionary spraying with fungicides. The best known of these is 'Bordeaux Mixture,' made by mixing lime with a solution of copper sulphate. Plants sprayed with this have their leaves coated with a thin layer of copper compound which kills the germinating spore and so prevents infection. Spraying must be done before infection takes place, and much has been done, especially on the Continent, to warn vine-growers of the approach of weather favouring the spread of the disease. Vineyards are usually sprayed several times in the season as a normal incident of cultivation, and the sight of the peasants with their knapsack sprayers, and of the blue-green of the vine leaves, is familiar to any one who has walked through a French vineyard.

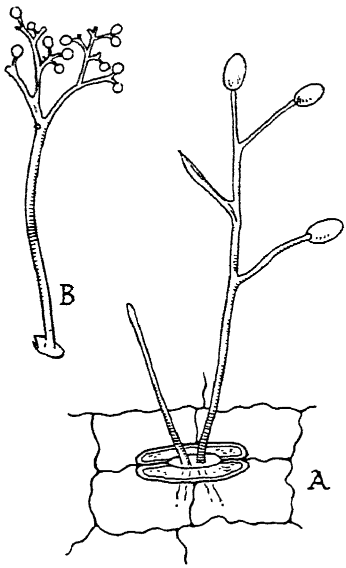

FIG. 339. PARASITIC FUNGI

A, *Phytophthora*, hyphae bearing sporangia growing from stoma of potato leaf. B, *Plasmopara*, hypha with sporangia.

PLANT DISEASES

The valuable potato crop is subject to serious damage by a variety of diseases which serve well to illustrate how such troubles are combated. **Corky scab** and **wart**, which directly damage the tubers, are both caused by lowly fungi, the reproductive bodies of which may lie dormant in the soil for many years, and are thus a danger to later crops. Happily all varieties of potato are not equally susceptible to disease, and wart is best avoided by planting one of the various immune varieties in districts where the trouble is serious. Varieties really

immune to corky scab are unfortunately not known, and sanitary measures have to be adopted here. Only sound tubers from districts unaffected by the disease should be planted. The ground must be thoroughly rid of diseased tubers, and a long interval should be allowed between crops so that the spores of the pathogenic organism die off.

One of the most insidious diseases of the potato and of many other plants, such as the tomato and the sugar-cane, is **virus disease.** It is really a group of diseases, which show themselves in the potato as mosaic and leaf-roll.

What are these 'filterable viruses' which have been so much investigated in recent years? The first to be recognized was that which causes 'mosaic disease' in the tobacco plant. It was shown in 1899 by the great Dutch bacteriologist Beijerinck that a healthy plant could be inoculated with filtered juice from diseased leaves, and it was noticed that the juice retained its virulence for many months. About the same time certain animal diseases were found to show similar relations. In 1898 Loeffler and Frosch showed that fluid taken from the blisters of animals suffering from foot-and-mouth disease was capable of producing the characteristic symptoms after it had been passed through a fine porcelain filter which kept back ordinary microbes. It was suggested that many familiar infectious or contagious diseases, in which it had been found impossible to detect a microbe, might be due to filterable viruses. The list of diseases now included under this heading must be at least fifty. As instances we may mention measles and scarlatina in man, pleuro-pneumonia and rinderpest in cattle, chicken plague and silkworm jaundice, and mosaic diseases in many plants like tomatoes, beans, and sugar-cane. It is probable that the filterable viruses do not form a homogeneous group. Thus it is probable that some contain an enzyme (or ferment) which does deadly dissolving work, and increases in amount as long as it has abundant material on which to operate. In most cases, however, the probability is that we have to do with living organisms comparable to virulent bacteria and Protozoa, but probably simpler than these. In some viruses, by using devices like centrifuging and the ultra-microscope, the presence of corpuscles has been successfully demonstrated, though the actual organisms have not been seen. In the disease called chicken plague the refractive haloes have been measured, and found to be smaller than our red blood corpuscles. But there is considerable range of size, some equalling small bacteria. In some instances the use of an 'ultra-filter' robs the fluid of its virulence, which supports the view that this is due to the presence of micro-organisms. In the spreading of 'mosaic diseases' from plant to plant sap-sucking and leaf-eating insects play their part, and a good illustration of the wheels within wheels may be found in the fact that insects may themselves

become victims. Thus the wilt diseases of the caterpillars of the nun moth and the gypsy moth are due to filterable viruses, and these two cases are interesting because the results are in man's favour, not against him. The gypsy moth caterpillar was accidentally introduced into America in 1869, and has done prodigious damage in defoliating trees. It is said that the appearance of wilt disease in these insects has probably done more to bring about the eradication of the pest than all man's efforts at control, energetic as these have been.

The Simpler Fungi: Summary

Returning to the simpler fungi we may note some of the more interesting points they illustrate. They are plants of the peculiar non-cellular or tubular type of construction which has led to no very great morphological advance. They are plants some of which are true aquatics, and in this offer evidence of their derivation from algae. Others have successfully invaded the land. Phytophthora and its allies hint at a recent invasion, for their reproductive bodies, which may be ciliated, show in this a character suited to life in water. In Mucor we have a real land plant with no hint of motile spores or sperms, and with spores, both sexual and asexual, which are resistant to drought. This fungus depends on air currents for its dispersal. The sporangial branches stand out into the air away from the moist substratum in which the mycelium must vegetate. To reach this position they must have some means of orientation, and they are, in fact, extremely sensitive to light, always growing towards it when it is not too strong. We say that they are positively **phototropic.**

Two modes of nutrition have been tried out successfully, the parasitic on living things, both plants and animals, and the saprophytic on all manner of dead organic débris. The decay of organic matter is in fact due to the action of micro-organisms, fungi, and bacteria. The micro-organism attacks the organic matter and breaks it down into simpler compounds, which it uses for its own nutrition—in other words, *digests* it; in the process the dead matter is destroyed, and comes once more into the circle of life. It seems likely that the first fungi must have been saprophytic. The parasitic life is more difficult, for it requires not only the power of assimilating organic material, but also that of attacking the living cell which always offers some resistance to an invader. A high degree of specialization is shown by such fungi as *Phytophthora infestans* and *Plasmopara viticola,* for these can live only on one particular host, the potato and the vine respectively. Some intimate relationship between the chemistry of the host and its parasite is indicated, but of its nature we are ignorant. Not all parasites are so specific; the fungus that causes 'damping off' of seedlings, *Pythium*

debaryanum, lives on a great variety of hosts. But later we shall find that specialization of the most complicated kind is of common occurrence. Both sexual and asexual reproduction occur in the simpler fungi, but there is no obvious alternation of generations. The possibilities that asexual reproduction affords of producing large numbers of spores, easily scattered by air currents, are made free use of in all classes of fungi.

Blue Moulds

The blue-green moulds are even more common than Mucor, and occur on every sort of organic matter, from bread, cheese, and jam, to damp clothes and boots. The blue colour is due to a dust of the asexual spores, which are the chief means of reproduction. As with Mucor, a branched mycelium penetrates the substratum and sends reproductive branches into the air. But here the hyphae are divided up by frequent cross-walls, and the progressive cellular type of construction obtains. The spores are of a type known as **conidia**. On the tips of the branches there are chains of small rounded spores, and these have been cut off by successive cross-walls. A touch or a breath of air fetches them loose; they germinate as soon as they reach favourable conditions and form new mycelia. These spores are probably derived from structures like the sporangia of Mucor or of Phytopthhora. Instead of forming sporangia with many spores inside, the higher fungi form many small sporangia, each with a single spore; the sporangium behaves like a spore. Sexual reproduction is common in some of the blue moulds, and less common in others. It consists essentially in a fusion between a male and a female hypha, and this is followed by the growing out from the female of a number of secondary hyphae, the ends of which swell up and, after various complicated nuclear events, form each a sporangium containing eight spores. The whole system of fertile hyphae becomes covered by a hard wall formed by the surrounding vegetative hyphae, and there is thus produced a little resistant fruiting body which rests and may be dispersed. The sack-like, fertile

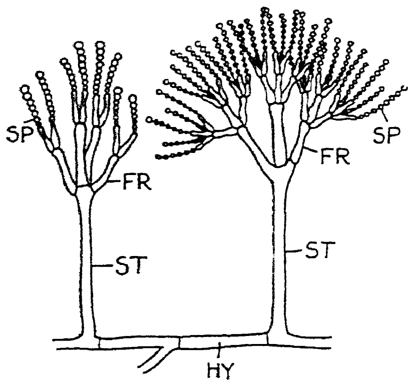

FIG. 340. *Penicillium*, THE BLUE MOULD

HY, hypha; ST, erect hypha; FR, spore-bearing hypha; SP, spores.

hypha with its eight spores is called an **ascus,** and the spores **ascospores.** These are characteristic of the whole group, and give it its name, *Ascomycetes*.

It will be understood that the vegetative mycelium is a sexual plant, and the fertile hyphae derived from the fertilized egg-cell form a little sporophyte generation. The whole process is reminiscent of what happens in the red seaweeds, and indeed the hypothesis has been put forward that it is from a stock like that of the red seaweeds that the higher fungi have been derived. The formation of conidia is a secondary type of asexual reproduction standing apart from the normal alternation. These conidia are formed by a great many of the ascomycetes, and are often referred to as **accessory spores.** Frequently they are much the most important means of reproduction. There are in fact many fungi which are known to produce only this type of spore. Some of them may have completely abandoned ascus formation, but for many it is probable that ascus formation has not yet been observed.

THE YEASTS

A fungus which belongs to this group but is very much simpler than most of its relatives—probably because it has lost some of the complexities of structure—is *Saccharomyces* or yeast. It is always present in the soil of vineyards. At its simplest it is a single oval cell, about one three-thousandth of an inch in length. It gives off buds which sometimes bud again, so that little temporary chains are formed. In unfavourable conditions it forms four spores within its cell, and when these are liberated they are readily carried about by insects or by the wind, and can remain for a time in a state of dormancy or latent life. When they light on grapes that have been wounded they become active in the exuding sweet juice and set up **fermentation.** From the wine-press the yeast plants pass to the vats and cause the fermentation which changes the sweet must into the alcoholic wine. The sugar of the must is split up into carbon dioxide and alcohol, besides by-products like glycerine and succinic acid. As the alcohol accumulates in the liquid the fermenting action is retarded, and when there is 14 per cent it stops. The fermentation is not dependent on the life of the yeast plant, for it can be produced by a juice obtained by grinding the yeast with sand and filtering under high pressure through porcelain. The active enzyme or ferment

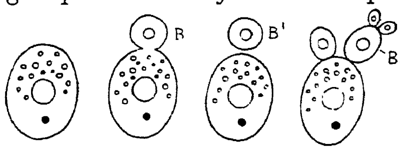

FIG. 341. DIAGRAM OF YEAST PLANT, *Saccharomyces*

B, B′, formation and liberation of a bud. BR, branching group of cells.

is known as zymase, and it may operate not only in producing wine and beer, koumiss and pulque, but in the formation of commercial ethyl alcohol from potatoes and the like, and in the lightening of bread by the production of gases that raise the dough. For special purposes man has reared many varieties of yeast, which are distinguished by their results, though they seem very much the same under the microscope.

Apart from these cultivated yeasts there are many that live in wild conditions, and some are found associated with the nectar of flowers. A dozen or so European forms are known that occur in the nectar of many different kinds of flowers, or on the surface of the stigma and other parts. They vary considerably in colour, for white, red, yellow, brown, and violet forms are known. They are distributed mainly by insects, the wind playing a lesser part. Cold climate and rainy weather hinder distribution.

The same wild yeasts may occur on different plants, and the same plant may show different yeasts at different times. T. Jimbo examined twenty-three species of plants in Japan and found twenty-two different yeasts, but he corroborates the conclusion that the same yeast may occur on different species of flowers. An interesting pink form is able to produce considerable quantities of oil both inside and outside the cell.

It may be recalled (cf. p. 312) that a great many yeasts are now known to occur in the food-canals of insects, especially among the cockroaches and related members of the order *Orthoptera*. In a considerable number of cases the evidence points to the conclusion that these yeasts are partners, which ferment the food in the alimentary tract and make it more available for the insect. Somewhat similar is the rôle that bacteria play in the food-canal of herbivorous animals, and in man's intestine in breaking down the cellulose of the food. Organic Nature is wonderfully interlinked.

A careful cultivation of pure strains of yeast under controlled conditions is a feature in modern brewing practice, for it makes it possible to turn out a uniform product. The presence of 'wild' yeasts or the intrusion of bacteria gives rise to all sorts of trouble in the beer—bad appearance, or flavour, or unwholesomeness. Following on the work of Pasteur, the great Danish breweries gave the lead in applying the methods of microbiology to the improvement of a beverage national in more countries than one.

Nor must we forget the most important use to which yeasts are put—the making of leavened bread. The 'little leaven that leaveneth the lump' was really a piece of dough kept from a former baking. When it was added to a new batch of dough it infected it with yeasts and so made it 'rise.' In baking, the alcohol formed is of no im-

portance, but the carbon dioxide produced along with it, almost weight for weight, collects as bubbles which, increasing in size, blow up the dough. Leaven is still used under primitive conditions; in the Canadian backwoods it is called ‘ sourdough ’; and so is the man who is an old enough hand to know how to use it. Here pure yeast is obtained in bricks, principally from the French cognac distilleries. Yeasts and blue moulds are extensively used in Japan to ferment rice and soy-beans in the preparation of various peculiar foods and sauces.

Useful Moulds

Moulds are as a rule undesirable. Some few even cause certain, happily uncommon, diseases in man. If they happen to grow on food they usually give it an unpleasant musty flavour. On one kind of food, however, blue mould is a welcome and necessary guest, and that is **cheese.** Many kinds of cheese ripen properly only with the help of certain moulds. The action is probably twofold; a certain amount of ‘ digestion ’ takes place; and the by-products of the mould's activity lend the cheese a characteristic flavour. The blue mould on Gorgonzola, Stilton, and Roquefort is a cause as well as an accompaniment of good condition. Different moulds affect different cheeses; their spores are always about the sheds in which the cheeses are stacked to ripen, and infection takes place naturally. One wishes that some of the modern factory products could acquire the unknown moulds which might convert them into something more like the natural article after which they are named.

Other Plant Diseases

Many of the Ascomycetes are parasitic and cause plant diseases. Perhaps the most famous is that which produces the *Ergot of rye* and of many other grasses. The mycelium vegetates in the flower-buds and forms a compacted mass of hyphae, a hard, dull purple object as thick as a match and half an inch long, which takes the place of the grain and projects from the ear in autumn. This is the ergot; it falls to the ground and rests till spring, when it produces little fruiting bodies like tiny round-headed clubs. The head harbours a number of flask-shaped cavities in which are produced ascospores. Conidia are also formed. The ergot damages the rye crop and it is dangerous to man as well, for it contains a poisonous alkaloid, **ergotin.** If ergot is milled with the grain, those who eat the bread may suffer from serious fits leading to death. But in the hands of the doctor ergotin is an important drug.

More familiar is the fungus which causes the mildew of the rose. We all know the white film which covers the leaf and leads to other unhealthy symptoms. The causal fungus, *Sphaerotheca*, is a parasite which lives, not in the leaf, but on its surface, sending minute suckers into the epidermal cells to nourish itself. Probably most of the damage is due to interference with proper illumination, though withdrawal of food counts for something. Conidia spread the pest, and as they germinate most successfully in damp weather, wet summers favour it. Spraying with various washes helps to check the disease; some roses, e.g. the ramblers, are peculiarly susceptible. The sexual reproductive organs are formed in autumn, usually on the stems of young shoots. Asci are produced and are enclosed in a hard black wall, the whole little fruit or **ascocarp** lying dormant on the soil through the winter. The black dots of the ascocarps can just be seen by the naked eye, speckling the white mycelium. Proper sanitary precautions are indicated here—the burning of all infected shoots in autumn and the clearing of litter from the soil. 'Unfortunately, if our neighbour is careless, our own precautions may be of little use. Two mildews on the gooseberry, and a mildew on the hop, do a great deal of damage. The American gooseberry mildew, especially when it first arrived in this country, was very destructive. This often happens when a pest is introduced into a new country. It probably meets hosts which are less resistant to it than those of its native land, and it often spreads with great rapidity and does much harm. Indeed, it might be said that all the worst plant diseases are foreigners. The same thing happens when diseases of the human race are introduced to new countries, as, for example, measles to the South Sea Islands.

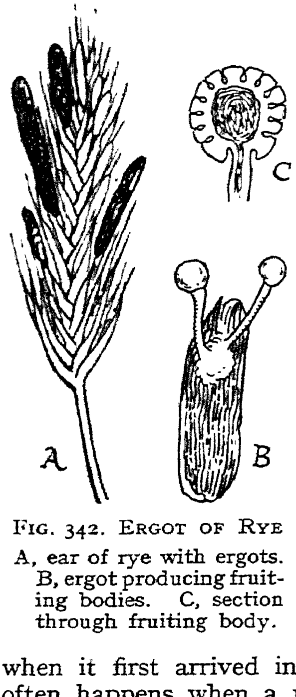

FIG. 342. ERGOT OF RYE
A, ear of rye with ergots. B, ergot producing fruiting bodies. C, section through fruiting body.

Sometimes parasitic fungi cause curious malformations in the plants they attack. The other day we came across a birch tree with over two dozen **witches' brooms.** It looked as if there were a rookery on a single tree, for every one admits the likeness of the witches' broom to an old nest. The tangled mass of twigs is, of course, an abnormality of growth; it is provoked by a number of fungi, mostly of the

genus called *Exoascus*, which do other things on other trees. The fungi send their threads into the skin of the host-plant, like grass roots growing in a shallow way in the ground. It is very usual for the broom to begin in a bud which has been infected by a spore during the previous summer. In some way not clearly understood, but with its analogies in galls and the like, the irritant presence of the fungus provokes the bud to send out numerous weak twigs. In the course of time there is a crowd of these twigs, many of them dead or half-dead. Spores are produced on the surface of the leaves of the broom and multiple infection occurs. It is interesting to notice that the leaves of the birch broom, which has been well called a 'bud-tumour,' are much larger than the ordinary leaves of the tree. Thus the presence of the fungoid threads is rather stimulating than destructive. Another interesting point is that it has been found possible to produce a witches' broom on an alder tree by artificial infection. In many cases in Nature it is probable that the infection begins by spores getting into the wounds made by mites.

FIG. 343. WITCHES' BROOM ON BIRCH TREE

THE LARGER ASCOMYCETES

Among the *Ascomycetes* are many which attain a considerable size, especially in their fruit bodies. The cup fungi (*Peziza*) are often to be found growing on decaying leaves in woods or in the turf of sandy places in autumn. The vegetative body is an unseen mycelium penetrating the ground, but the fruiting bodies are fleshy cups ranging from a quarter of an inch to two or three inches in diameter in different species. In some they have very beautiful colouring, clear brown or brilliant scarlet. The inside of the cup is lined with millions of asci, each with its eight spores. When they are ripe, the asci burst and shoot out the spores to a little distance; thus the spores are the more easily caught by the scattering breath of the wind. A large woodland Ascomycete not very common in this country is the edible **morel.** It is stalked, and has a large corrugated head. Though something like a toadstool, it is no relation of that group.

Perhaps the most famous and sought after of edible fungi are the

truffles, which are Ascomycetes leading a curious subterranean existence. The vegetative body consists of a widespread branching mycelium which probably lives in close association with the roots of the trees under which it grows—in England most often the beech, in France the oak and holm-oak or Ilex. The truffle is the fruiting body, a firm mass of interwoven hyphae containing innumerable asci with their spores. In truffle regions spores are often introduced into the soil of suitable woods to improve the production. Its presence is recognized by the scent which accompanies the flavour beloved by the gastronome. But the human nose is not generally sharp enough, and trained dogs and pigs are brought in to help the truffle-gatherer. The French poodle, keen of scent and amenable in temper, is led through the wood till he stops and starts scratching the earth; he is then removed and his master grubs up the truffles with a fork. When truffles are abundant pigs are utilized. The largest supply comes from France, though truffles are found in our southern beech woods on the chalk of the Downs.

The Rusts and Smuts

On the lower side of blackberry leaves in autumn we may often see patches of the purple-black spores of the blackberry rust, *Phragmidium violaceum.* Rust fungi attack many plants, and perhaps the most important is the black rust which grows on the wheat and is caused by another fungus, *Puccinia graminis*. Long streaks of bright orange spores on leaf and haulm in summer give place to a very dark brown later in the year. It is not the only rust which lives on the wheat, but it has probably done more damage all the world over than any other, and its story exhibits the behaviour of these remarkable parasites in all its complexity. The mycelium of the rust lives within the tissues of leaf and stem of the wheat plant. The hyphae do not penetrate the cells, but send little suckers into them and so withdraw food-supplies. The rust does not kill its host, but it seriously draws on its organic matter and causes lesions where the masses of spores burst through to the surface. The total effect of a bad attack is a serious loss of both grain and straw.

In summer the spore-masses are formed under the epidermis and burst through it in orange streaks. The spores are oval bodies borne on a stalk and, becoming detached, they are scattered by the wind. Lighting on another wheat leaf in moist weather, they put out germ-tubes and infect through the stomata. This process may be repeated several times, so that repeated infection occurs. Late in summer the same mycelium forms spores of a different kind, dark in colour, with very thick walls, and each composed of two cells: really these are two

spores together. In Phragmidium there is a chain of five or six. These are the resisting, resting spores, and they lie about the fields in winter on stubble and ungarnered gleanings, and germinate in spring. From each cell comes a slender tube which is cut into four cells by three cross-walls. Each cell in turn puts out a short tube, from the tip of which a single white thin-walled spore is cut off. This four-spore body is called a **basidium**, and the spores are **basidiospores.** The basidium is characteristic of the whole class of *Basidiomycetes*, just as the ascus is characteristic of the whole class of *Ascomycetes*. 'By their fruits shall ye know them' applies not only to the seed plants but also to these more lowly organisms. The basidiospores are, as usual, scattered by the wind and can germinate successfully only on a suitable leaf. But the suitable leaf is not that of the wheat, but of the barberry (*Berberis*).

In the infected barberry leaf a mycelium is formed, and, when it has developed sufficiently, some of its cells undergo a sexual fusion in pairs, and then grow out into long chains of rounded spores. Groups of these chains are enclosed together in common envelopes, and clusters of these appear on the leaf surface as rather thick yellow patches. The envelopes open and the chains of spores lie in the bottom of minute cups. This fructification is known as a **'cluster-cup.'** Yet another kind of fructification consists of minute flask-shaped receptacles which open on the upper-surface of the leaf. The function of these has long been a puzzle. Recently it has been suggested that their spores also infect the barberry leaf, where they produce a second mycelium the presence of which is necessary to the sexual fusion.

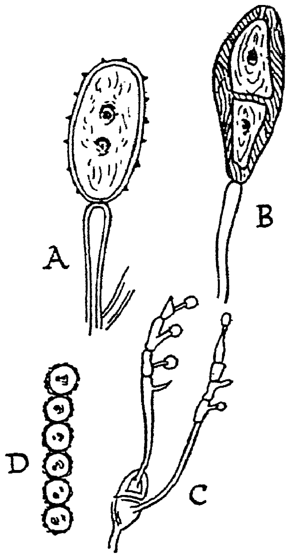

FIG. 344. SPORES OF THE RUST FUNGUS, *Puccinia*

A, summer spore. B, winter spore. C, germinating winter spore with basidiospores. D, chain of aecidiospores.

The **aecidiospores** formed in the cluster-cups in spring infect the young wheat plants and the life-cycle is complete. It will be clear that we have before us a definite alternation of generations—sexual on the barberry, and asexual on the wheat. A peculiar feature is that, although pairs of cells fuse, preparatory to the formation of the spore-chains in the cluster-cups, the *nuclei* of these cells do not fuse, but lie side by side in the fusion-cell, and, as it divides, divide simultaneously.

This goes on through the whole of the asexual generation, and the summer and winter spores each contain two nuclei. Then before the winter spore germinates, its two nuclei fuse. Immediately after this, in the formation of the four basidiospores, the **reduction-division** (p. 1063) occurs. The completion of the sexual process is delayed through a whole asexual generation.

The most remarkable new feature shown by this parasite is the necessity for two hosts. Many other rusts show the same thing. The cluster-cups which are often to be seen on the coltsfoot are linked to a rust which attacks the soft grass (*Holcus mollis*) and other grasses. The rust of the sedge produces cluster-cups on the nettle. The plum rust has its cluster-cups on the garden anemones. Other rusts have their various stages on the same host-plant. Thus the garden mint may be seen to bear yellow cluster-cups in early summer and brown patches of winter spores later; and both stages of the blackberry rust occur on that plant. Many rusts have lost one or more of their stages. The hollyhock rust has only the winter spores. A possible biological advantage in using two hosts is that of prolonging the vegetative period by spreading it over hosts available at different times of the year. The habit is certainly indicative of a high degree of specialization. This is still further emphasized by the fact that some rust species are divided into races, in appearance exactly alike, but growing on distinct though closely related host-plants. Thus *Puccinia graminis* includes races which grow on rye and barley, on oats, and on wheat.

The full story of the wheat rust was demonstrated in 1864 by the great German mycologist de Bary, who laid the foundation of our modern knowledge of the Fungi. It was a history which could yield its secrets only to the most acute investigation. Yet it had long been suspected by the practical man that there was some sort of connection between the presence of barberry and bad attacks of wheat rust. As far back as 1630 the Parliament of Rouen had decreed the extirpation of barberry in the neighbourhood of wheat-fields, and in the eighteenth century the State of Massachusetts had taken similar action. The reason of the connection was unknown and various mysterious exhalations and influences were invoked to explain it. But, as has happened more than once, the practical farmer had operated with the correct end of the stick centuries before the scientist discovered the explanation. The rooting out of barberries is not always very successful in combating the pest, because the rust can sometimes dispense with the winter spore stage. The summer spores can survive on the soil through a mild winter, and the rust may pass the winter on various grasses. There is, too, another rust—the yellow rust—which also attacks wheat and other cereals, and is one of those

which require only the one host. It has been possible to breed an excellent wheat—the Little Joss—which is nearly immune to attacks of yellow rust and is now largely grown in the east of England.

The **smuts** form another group of parasitic Basidiomycetes which do much damage to cereals. Young plants are infected as they pierce the soil from spores germinating there. The mycelium enters the growing regions and grows with the host. It forms its spores in the ears, which it fills with a sooty mass. This, and the deformed head, make the disease conspicuous. Healthy grains are powdered with the spores during threshing and carry them to the soil when they are dispersed. It is possible, however, to secure complete disinfection by treating the seed grain with various washes, such as weak formalin. **Stinking smut** and **bunt** are other diseases caused by smut fungi. Among the plants attacked by these fungi are oats, barley, wheat, maize, sugar-cane, and onion.

Toadstools and Mushrooms

The most familiar of all fungi are the toadstools. They are the largest, and in other ways the most conspicuous, members of the group, and they include the only fungi of first-class importance as foods. Their vegetative body is still on a very low stage of organization, for it consists of no more than the customary weft of mycelium permeating the soil. Sometimes it is spun into thick brown strands. The toadstool is the fruiting body; but even though it is large and firm it is built on the plan of the red seaweeds and has not developed a true tissue structure.

Fear of fungi is widespread in Britain. Obstinate ignorance condemns a fascinating class of plants as dangerous. Even the palatable mushroom is not accepted by many without a big mark of interrogation. But there is no denying the usefulness of fungi in the economy of Nature in cleaning away dead organic matter. They help to keep the world fresh, and most of them do this very artistically.

When we walk through a damp wood, we see that one factor in the fascination of fungi is their beauty of form. Not only does one see 'fair umbrellas furl'd or spread, a Grecian shield and a prelate's crown, a Freedom's cap and a friar's cowl,' one finds goblets and chalices, corals and sponges, a flimsy cage for a hop-o'-my-thumb, and a bird's nest filled with eggs. Even the big dryad's saddle projecting from the doomed tree has its beauty, especially when one gets a glimpse of the dryad mounted, but it is among the small fungi that one finds the most exquisite architecture. Add to that the wonderful colouring—from crimson and scarlet to golden yellow and ivory white. There is a charm, too, in the rapid transient growth—how soon they

strike their tents and are gone! What delicacy of build in many cases; they are like little fountains of protoplasm.

In Great Britain we are too much obsessed by the motto 'Safety First,' and we are therefore apt to restrict our menus unnecessarily. Little use is made of 'summer truffles,' or of 'common parasols,' or of 'horse mushrooms,' or of 'blewits,' all of which are edible. The consumption is practically restricted to the common mushroom, which is unmistakable and readily cultivated. The fungus markets on the Continent show a much greater variety than can be seen at Covent Garden. All the rules for distinguishing palatable from poisonous fungi have their exceptions, and the modern pace is too rapid to allow of any systematic continuance of the patient experimenting by which prehistoric man learned to discriminate between the useful and the fatal.

Like everything in the least degree queer, fungi have been much used in medicine, but the only one in the British Pharmacopoeia of to-day is the **ergot** (p. 1083) which grows on the flowers of rye. It furnishes a drug of the first importance, especially as a stimulant to muscular contraction. The **common polypory** or purging agaric, that used to be of frequent medicinal use and of great reputation, seems to have fallen from its high estate. There are related kinds, however, that are used in making tinder and razor-strops, corks, and snuff. Even as lately as the war of 1914–18 a use was made of 'luminous wood' for putting on the straps of steel helmets and on the fore-sights of rifles. The luminosity is due to the threadwork of a fungus spreading in decaying wood. This is what is referred to in Huckleberry Finn's adventures —'them rotten chunks that 's called fox-fire and just makes a soft kind of glow when you lay them in a dark place.'

On the debit side, however, must be placed the fell poisonousness of many fungi. The poisons seem to be waste-products formed in the course of the plant's chemical routine (or metabolism); they are alkaloids, glucosides, toxalbumins, and the like; they are well illustrated by the common *Amanita phalloides*, which has unfortunately a harmless appearance and a not unpleasant taste and smell. It is responsible for most of the fatalities from fungus-eating, yet snails thrive on it! One of its relatives is used in Siberia and Kamchatka as an intoxicant (see *The Purple Pileus* of H. G. Wells). We must not dwell on this seamy side, but we cannot ignore the fungi that cause poisoning, like the ergot among the rye; the 'ringworm' of children—the 'human fairy ring,' as this minute fungus has been called; and the 'trench feet' of our soldiers—also due to a fungus.

There is always a charm in the queer, and fungi are full of queernesses. There is the often startling rapidity of growth, as in the **stinkhorn** that may rise six inches in two hours, or the *Polyporus* that

may attain a weight of thirty-four pounds in three weeks. There is their watery strength, lifting a large hearthstone and a cask of wine. There is their luminescence too, another strange transformation of energy. And there are the puzzles like that of the fairy rings.

MUSHROOMS.—Most fungi are wild, but in the mushroom (*Agaricus campestris or Psalliota campestris*) we have a true cultivated plant perhaps derived from its wild relative the horse mushroom, which we may pick up in pastures in autumn.

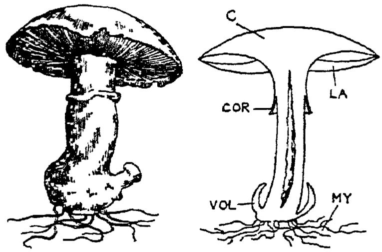

FIG. 345. THE MUSHROOM, *Agaricus*
On the right a section showing, C, the cap; LA, the gills; COR, the remains of the velum; VOL, the remains of the volva; MY, the mycelium.

If we wish to grow mushrooms we buy some 'spawn' from a nurseryman. This consists of a network of interwoven whitish threads or hyphae, which spread in all directions in the soil, absorbing water and salts and decaying organic matter. They form the feeding and spreading part of the mushroom—the nutritive and vegetative part, as we say.

After the feltwork has spread considerably, some of the threads near the surface combine to form protruding 'buttons,' which grow into 'mushrooms' or fruiting bodies. A mushroom consists of an umbrella-like **cap** or **pileus,** supported on a stout **stipe,** and bearing on its under-surface a number of delicate, radiating, vertical plates or **gills.** These are covered with a spore-making skin (the **hymenium**). In the young stages the delicate gills are protected by being on the under-surface of the umbrella, and by a veil which extends from the edge of the cap to the stem or stalk. As the cap grows there is necessarily a breakage of the veil, remains of which are left at the edge of the cap and as a *ring* round the stem. When the gills are exposed by the breakage of the veil, the spores are shed into the air, and are carried hither and thither by every wind that blows. It has been estimated that one mushroom may produce 1,800 millions of spores, and this is enough to show that it is a lucky spore that finds a suitable place for sprouting and forming a new feltwork or mycelium, from which after a while a mushroom grows. Nature works with a big margin.

The mushroom grows in well-decayed horse-dung and earth; it is a saprophyte. But many toadstools have a more complicated existence. This is notably so with the forest forms, some of which have long been known to grow in association with particular trees; thus *Boletus elegans*, one of the pore fungi, always grows under larch, *Boletus luteus* grows with the pine, and *Boletus rufus* with the aspen. The reason is

that the mycelia of these fungi live in close union with the roots of the trees. The tips of young roots are covered with a hyphal weft, and tend to become thickened and closely branched. This association of root and fungus is called **mycorhiza** or fungus-root. It seems that the fungus draws nourishment from the tree root, and that, in return, it passes into it, from the soil, water and salts, and also makes available the insoluble organic nitrogen-compounds present in leaf-mould and humus. Neither partner is absolutely dependent on the other; tree and fungus can be grown apart. But in Nature the solitary fungus does not fruit, and the uninfected tree grows less well than when it is provided with mycorhiza. This is an example of **symbiosis**, or living together to mutual benefit, notable because the two partners belong to such widely different classes of plants.

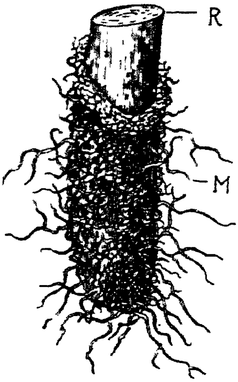

FIG. 346. MYCORHIZA
R, tip of tree rootlet covered with fungal hyphae, M.

An interesting phenomenon associated with toadstool growth in meadows is the formation of '**fairy rings**.' Round the circumference of a circle, which may be a few feet or many yards across, a crop of toadstools appears. It dies down and is succeeded by a further crop in a larger circle, and so on. Several crops may occur in a year, or several years may elapse between successive crops. From measurements of growth-rate it has been reckoned that rings three or four centuries old are still active. The ring formation is due to the exhaustion of the soil by the mycelium, so that, as it grows, it must spread *outwards* to find adequate nourishment. If the original infection by germinating spores started at one point, and growth has been equal in all directions, a ring will be the result. Within the ring the grass is often very luxuriant and dark green. The fungus has made available rich supplies of nitrogen-compounds from which higher plants can benefit. In earlier days the fairy ring was a natural circle of magic.

Not all the toadstools bear their spores on gills as does the mushroom. Some, like Boletus already mentioned, and the bracket fungi, have their lower surface pitted by innumerable pores, and the walls of these bear the spore-producing hymenium. To this group belongs the pestilential ' dry-rot ' fungus, the mycelium of which attacks woodwork in damp and airless situations, and, feeding in it, reduces it to a spongy pulp. After the work of destruction is done, the fructifications are formed in the light and air: they may even appear outside the stonework within which lies the damaged wood. They have a coarse honeycombed surface. Some toadstools attack both dead wood and

living plants. The worst of these is the honey fungus (*Armillaria melleus*), with clusters of buff-coloured fruiting bodies often to be seen around a decaying stump. This fungus usually starts on such a stump, and then sends through the soil long strands of mycelium of the thickness and nearly the colour of bootlaces. These can infect living roots, especially if the tree is not in a healthy condition. The fungus then spreads upwards between wood and bark, destroys the wood, and ultimately brings down the tree. The elm is particularly liable to this disease.

The stinkhorns, puffballs, and earth-stars belong to a curious group in which the spores are formed inside the fruiting body, and are liberated either by a pore, as in the puffballs, or by the liquefaction of the external layers, as in the stinkhorns.

Despite the great variety of their fruiting bodies and the great many ways in which their spores are borne, all these large fungi are fundamentally similar in structure and reproduction. Structurally they are at a low level. The fruiting body may be large and fine, but, like the vegetative mycelium, it is always a closely woven mass of hyphae and is never formed of true tissue. The spores are basidiospores produced in groups of four on swollen club-shaped basidia, which differ in appearance, but not in their nature, from those of the rusts. In many toadstools there is a sexual fusion between neighbouring cells, and this results in a mycelium in which all the cells are bi-nucleate until fusion of the nuclei takes place in the young basidium. In many species fusion takes place only between the cells of different mycelia, the same type of sexuality existing throughout, as in the case of Mucor. In some the sexuality is more complex than in any other living things. There may be four classes of mycelia; a cell of any one can fuse with a cell of any other, but not with a cell of a mycelium of its own class. In a sense there are *four different sexes*.

CHAPTER V

THE LICHENS

Dual plants—The life of Lichens—Useful Lichens.

Dual Plants

The most remarkable instance of symbiosis, or living together to the common weal, in the plant kingdom, perhaps among all living things, is afforded by the Lichens. These familiar plants exhibit a partnership between Algae and Fungi. Many different fungal, and a smaller number of algal species, can enter into this partnership, and the result is the formation of a large number of distinct forms. A particular partnership has its own individual appearance, an appearance entirely different from that of either partner growing alone; something new and unique has come out of each combination. For a long time the apparently justifiable opinion was held that lichens were not of a dual nature, but were organisms of independent dignity and of a peculiar nature, a class to be placed alongside the other main classes of plants. It was only when the two components had been artificially separated, grown apart, and then reunited to form once more a lichen, that the question of their nature was finally settled. The credit of synthesizing a lichen is due to the French botanist, Gaston Bonnier.

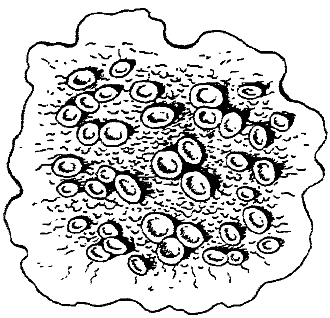

Fig. 347. Lichen Growing on Bark of Tree

A common lichen which may serve as a type is the dog's-tooth lichen (*Peltigera canina*), found growing amongst moss and grass, especially in rather shady places. It is a flat thallus, of a dull green colour when wet, and turning greyish when dry. On the under-surface it is covered with grey hairy rhizoids. These penetrate the substratum of half-decayed mould and even pierce living moss leaves. They are organs of attachment and also draw in some water. A large specimen of this lichen may be as big as the palm of the hand and as thick as a piece of brown paper. The thallus consists of a weft of fungus hyphae,

close above and loose below. Just under the upper-surface is a region in which there are numerous groups of bluish-green algal cells. It is their presence which gives the plant its greenish colour. Algal cells are unusually abundant in *Peltigera*; most lichens have a greyish hue, for, although all have algal cells, these may not be sufficiently abundant to impress the whole plant with their colour. The algal cells are wrapped closely around by the fungal hyphae, so that the two organisms are in the most intimate connection. The algal partner, or species very similar to it, may occur independently in Nature. The fungus lives only in the association. The fungus, except in a few rare tropical lichens, is always an *Ascomycete*. On the margin of the thallus of Peltigera may be found flat brown disks which are the fungus fructifications, and these are covered with a layer of **asci**. When the spores germinate in Nature they can only grow if they chance to be in contact with a suitable algal partner. Many lichens reproduce chiefly by breaking off little powdery fragments, each consisting of a few algal cells wrapped in a tuft of hyphae —a chip, as it were, of the old block, which, blown about by the wind, may find a favourable foothold and grow into a new plant.

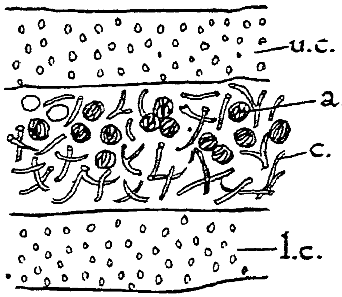

FIG. 348. SECTION THROUGH LICHEN

uc and *lc*, the upper and lower cortical regions where the fungus hyphae are closely interwoven; *c*, the central region with loosely woven hyphae; *a*, algal cells.

THE LIFE OF LICHENS

In their dual common life the fungus protects the alga from drought, and supplies it with water, salts, and carbon dioxide; the alga assimilates and supplies the organic food. The actual mass of the fungus is much greater than that of its partner, and, if only because of this, the total growth must be slow, for a small number of assimilating cells has to supply a big plant. But growth is slow for another reason —because lichens habitually suffer from drought. Most lichens live under worse conditions than Peltigera, and occur clinging to the bark of trees or to stones. Their water-supply is intermittent and precarious, and yet only when they are water-saturated can they build up food at top speed. The period of saturation is often short, and often occurs at night or in dull, cold weather when photosynthesis is slowed down by other factors. No living thing can have it both ways. The lichens are successful because they are

the most drought-resisting of all plants. They can dry completely up and, with the first shower of rain, regain their full vitality. Because of this they can occupy situations so unfavourable that no other plant can survive or even start life in them. In such situations they are free from the competition of more vigorous organisms. But for this they must give up the capacity for efficient and continuous photosynthesis; and so they are condemned to a growth so slow that it may often be measured only by millimetres in the year.

In Nature the lichens play an important part in breaking down rocks. They eat slowly into the surface, largely by the action of the carbon dioxide they give off in respiring, and by the excretion of special acids. The crevices thus formed allow water to collect, freeze in winter, and so carry on the work of disruption; for freezing water can crack a rock as easily as it does a water-pipe. To the rock debris the remains of lichens add a little organic matter and thus begins the formation of **soil.** Slate and even glass can be eaten into, and lichens have been known to cause much damage to old church windows. Slow as their growth is, the wide scattering of their reproductive bodies, and their capacity for making the most of very unfavourable conditions, have enabled the lichens to colonize the most unlikely places—on the bark of an old apple tree, the stone of an old church, the detritus of the mountain-top, and the spray-washed face of a cliff they are equally at home.

An interesting study that finds many illustrations is the succession of different forms of life in the same place. We see this if we watch a clearing in the forest for a number of years in succession. We see it if we make a careful study of the sequence of living creatures in a hay infusion—one type following another till nothing is left but water. The successive types or associations of types do something to the environment that opens the door to successors and, directly or indirectly, involves their own exit. A good illustration has been recently disclosed by Mr. C. C. Plitt, who has made a study of **lichen succession.** When we climb a mountain above the region of grasses and mosses and Alpines, we reach a lichen vegetation clinging to the bare rocks and assisting in the very beginning of soil-making. These lichens succeed in gaining a livelihood where nothing else will live because they are, as we have explained, *dual* plants. What neither plant could do alone, the partners can do together. They live and thrive, but those in very exposed situations are mostly of a closely clinging, encrusting type. In less exposed places the same substratum, whether rock or tree, shows a succession. The encrusting species are succeeded by leafy species. Then there is a struggle for existence between these; and the more loosely growing forms with ascending margins replace those that cling very closely. Later on, there arise shrubby species

like the reindeer moss, suggestive of miniature fruiting shrubs. The trunk of a tree sometimes shows a prolonged succession, ending in the greyish pendent *Usnea*, old-man's-beard, having sole possession. This is one aspect of the struggle for existence.

Useful Lichens

There are some lichens of economic importance. Thus the **Iceland moss** (*Cetraria islandica*) is a lichen which is eaten by northern peoples. The **manna**, which fed the children of Israel in the wilderness, is a lichen, or rather it represents several lichen species, belonging to the genus *Lecanora*. It grows over enormous areas in the south-west of Asia, usually on the soil or on small stones. Growth is rather vigorous, especially in thickness, and the lichens often become detached from the substratum and roll up into little grains. These are collected by the wind, or more often by freshets of rain-water. Such collected heaps on a large scale are exceptional, but 'manna rains' have been recorded every five or ten years in modern times. The manna is still used by Asiatic tribes instead of grain in years of famine. A second manna, entirely different, is of insect origin, allied to the honey-dew of aphids. Another useful lichen, *Cladonia rangiferina*, is the so-called **reindeer moss**, one of the dominant plants of the northern tundras, and as important grazing for flocks of reindeer as is grass for our cattle.

Important in a very different connection is *Rocella tinctoria*, which grows on rocky coasts in the south of Europe. It yields the fine purple dye **orchil**, and from this is obtained the **litmus** used in every chemical laboratory. Red, yellow, and brown dyes are still obtained from lichens in the Highlands of Scotland, where they are used for dyeing homespuns.

Apart from their action in disintegrating stones, which may damage old buildings, lichens do little harm. The vigorous growth of *Usnea* and others sometimes seen on old fruit trees is certainly not beneficial, but it can be easily cleaned away by spraying, or even by scrubbing with a suitable disinfectant. In industrial towns lichens do not flourish; the smoky, acid-laden air is fatal to them.

CHAPTER VI

BACTERIA AND BLUE-GREEN ALGAE

Bacteria—The structure and life of Bacteria—Practical bacteriology—The Blue-green Algae: Cyanophyceae.

BACTERIA

TOWARDS the end of the seventeenth century some keen eyes, using very indifferent lenses of glass, began to discover the invisible world of life. They detected the abundant presence of very minute living creatures in stagnant water, in decaying substances, even in man's mouth! The great importance of this discovery of a new world—invisible without lenses or microscopes—was that it made many visible events more intelligible. It was shown, for instance, that there are living creatures so minute that they, or their germs, may be carried about by currents of air and may find access through minute crevices into vessels containing food.

One of these pioneer microscopists was Anton van Leeuwenhoek, a merchant of Delft in Holland, who had no fewer than fifty communications published in the *Philosophical Transactions* of the Royal Society of London in the fifty years between 1672 and 1722. This remarkable man was probably the first to describe what we now call *bacteria*—a name invented by one of his successors, Ehrenberg (1838), just as the name *bacillus*, often used to-day, was suggested by another distinguished investigator, O. F. Müller. Both words, *bacterium* and *bacillus*, refer to the rodlet-like form of the creatures in question—the smallest and yet in some ways the most powerful organisms in the world. For bacteria are the causes of most of the rotting or putrefaction, which brings the dead bodies of plants and animals back into the circulation of matter. Bacteria are also the causes of some of the most serious diseases, such as plague and tuberculosis; and, as we shall notice, they are wrapped up in the bundle of life in many different ways.

It is now generally recognized that bacteria are very minute plants, which some authorities would rank along with the fungi, while others regard them as nearer certain very simple freshwater algae known as the *Cyanophyceae*. But the fact is that they are so peculiar that they

might almost be regarded as *a little kingdom by themselves.* They are unprovided with the usual green pigment, and are therefore unable to feed except on organic substances previously worked up by green plants or by animals.

The Structure and Life of Bacteria

In its form a bacterium may be a rodlet, or an oval, or a sphere, or a spiral; and there are yet other shapes. The whole creature is usually one cell, but the nucleus, which is the characteristic kernel of a cell, is absent or indistinct. But there are sometimes granules of **chromatin**, the material that is characteristic of ordinary nuclei. The outer portion of the bacterium is denser than the interior, and some of the resting stages (spores), well known to be very difficult to kill, have a firm outer wall. A remarkable feature in many bacteria is the formation of locomotor lashes or **cilia**. There may be only one, or one at each end, or three or four at each end. The bacillus of typhoid fever has numerous scattered cilia. In all cases the cilia are locomotor structures, enabling the bacterium to move in a fluid; but they are shed when the creature settles down.

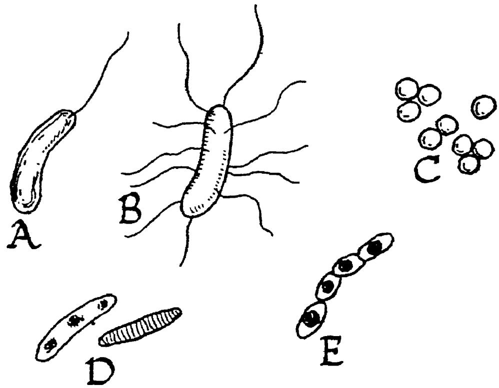

FIG. 349. DISEASE-CAUSING BACTERIA

A, cholera bacillus. B, typhus bacillus. C, pus cocci. D, tubercle bacilli. E, anthrax bacilli.

The bacterium multiplies by simple fission; it grows in length, splits across, and two have taken its place. Under favourable conditions a bacterium may divide once every twenty minutes. A simple calculation shows that in a day seventy-two generations will have passed, approximately the number of generations of man in our era. From a single micro-organism the descendants in a day might number more than 4,700,000,000,000,000,000,000. It is not in the stars and atoms alone that the amateur of big numbers can find his material. A bacterium may be only one-five-thousandth of an inch in length, but even so small a body multiplied so many times bulks large. After a few days of such multiplication the original microbe would have produced a

mass of matter as large as our earth. It does not do so, for growth is checked by lack of food, and also by a sort of self-poisoning. The results of its own chemical activity—the simplest case being the formation of carbon dioxide in respiration—act as a brake on its growth. Moreover, bacteria are the food of many micro-organisms of the animal kingdom.

Practical Bacteriology

The bacteriologist has to investigate the activities of many sorts of bacteria, and to do so he must cultivate them. Suppose he wishes to find out what species are present in a sample of water. He mixes a few drops with some sterile nutrient jelly, warmed just enough to melt it, and pours a thin layer into a glass dish which is carefully covered. This is incubated at a suitable temperature, and two days later the surface of the jelly is dotted with little opaque spots about one-tenth of an inch across. Each dot is a colony of millions of bacteria, derived from a single microbe in the water. The number of colonies at once gives an estimate of the number of bacteria present in the water sample. Different species of bacteria are indicated by differences in the form, colour, and position of the colonies. Here is a demonstration of the enormous power of reproduction of these organisms, for in two days the progeny of an invisible microbe bulk so large that they are easily visible to the naked eye. The bacteriologist may now examine any particular colony microscopically, and he can grow further supplies by infecting tubes of gelatine or nutrient broth from any one of the colonies.

Bacteria require for their nutrition and growth a supply of suitable organic matter and a favourable temperature. The different sorts vary much in their requirements. There are bacteria which can grow on a tallow candle, and others which must be pampered with beef extract. There are bacteria which can survive only in almost ice-cold water, and others which live in hot springs. Some are responsible for the 'heating' of damp straw and hay, and multiply at the high temperatures they themselves have produced. Some bacteria require air and others grow only in its absence. But the majority of bacteria which are important to man by causing disease or spoiling food, require rich organic food and a moderate temperature.

The ways in which bacterial activity is combated are determined by their conditions of growth. Milk sours rapidly in a jug which has previously had milk in it, for the jug is contaminated by microbes which have had time to multiply. So we scald the jug and the heat destroys the microbes; the souring of the milk is much delayed. When food is canned it is carefully sterilized by heat so that no bacteria may

be present in the closed tin. The process of **pasteurization of milk** is one of **heat sterilization,** which destroys most of the bacteria present—and in particular those which cause tuberculosis. The temperature used is only 80° C., and this has the advantage that it does not give the milk a boiled flavour. In bottling fruit we sterilize it by heating it nearly to the boiling-point. This temperature does not destroy the resistant spores which are formed by some bacteria. Such bacteria are abundant in soil, so that we cannot bottle carrots, for example, in this way. But carrots may be sterilized by heating them to a higher temperature in special apparatus under pressure. It is in this way that bottled carrots have been treated.

We can also preserve food by drying it. Pemmican is flesh preserved in this way. The absence of sufficient moisture keeps down bacterial growth. Dried food is often heavily salted, as for example in the case of cod and related fishes; the high concentration of salt is unfavourable to bacterial growth. Cereal grain is a naturally dried food, and it is the easiest to store since it needs no special preparation. It might be said that the growth of civilizations has depended on the availability of the cereals which, even in primitive conditions, could be safely stored in bulk.

Finally, we may preserve food simply by keeping it at a temperature too low for the growth of bacteria. This method has come into great prominence in modern times with the advance in methods of **refrigeration.** Nowadays we can preserve by chilling such diverse foods as beef and mutton, fish, eggs, and fruit. They may be preserved in fresh condition almost indefinitely at low temperatures, but there are great difficulties in securing ideal refrigeration, that is, freedom from decay combined with maintenance of fresh flavour. Much research is carried on to discover the exact conditions of temperature and moisture necessary for each particular kind of food. The advance in technique may be appreciated by any one who keeps an eye on the fruiterers' shops. In recent years foreign fruits have become commonly available which used to be costly rarities or unknown in Britain.

The distinctive action of bacteria in causing decay and disease is only too familiar, but we must insist once more on a point already made—that the process of decay is a necessary one. The part played by bacteria, and by fungi, in reducing dead organic matter to simpler compounds which can once more be used by other living things, is essential in keeping the wheels of life on our planet going round. Another important fact is that many bacteria play a special part in maintaining the supplies of combined nitrogen required by the higher plants. We shall have occasion to mention these more particularly in a later chapter.

The Blue-green Algae: Cyanophyceae

A bluish-green scum may sometimes be seen in the pools of water near a farm midden. It is due to an organism which may be classed among the Algae, since it possesses chlorophyll. It consists of very slender filaments built up of a series of shallow cells. But the pigment is *diffused* throughout the protoplasm, and in other ways the structure of the cell and its wall is more nearly that of a bacterium than of an alga. The plant might almost be called a filamentous bacterium with chlorophyll. The relationship to the bacteria becomes more marked if we mention that filamentous forms are not unknown in the latter group. The blue tinge is due to the presence of the pigment **phycocyanin**, which we have already noticed as occurring in the red seaweeds.

There are many different species of blue-green algae. Some are unicellular, some filamentous or branched, and others are colonial: most are inconspicuous, living in stagnant water or on damp soil. One, a form consisting of coiled filaments, secretes masses of jelly and so forms lumps the size of a walnut. These may be found about the banks of slow rivulets and are known as **witches' butter.** The name of this form is *Nostoc*. The blue-green algae often take a prominent part in the spring resurgence of growth which brings about the 'breaking of the meres.'

The possession of chlorophyll gives these organisms the power of photosynthesis, but their frequent preference for stagnant water suggests that they may also use decaying organic matter. Blue-green algae often form the algal partner in the lichen symbiosis.

Both bacteria and blue-green algae are groups of organisms which stand apart from the main lines of plant evolution. It may be that bacteria are degenerate fungi. Or it may be that they have arisen from the blue-green algae by loss of pigment. Possibly the blue-green algae have taken their origin from some very primitive stock far back below the level of the true algae. They have never elaborated the advanced type of cell-structure seen in other plants, and so have never been able to go beyond the very simple filamentous type of structure. In the vast majority there is no trace of sexual reproduction.

CHAPTER VII

Mosses and Liverworts: Bryophyta

The Mosses: Musci—Reproduction in Mosses—The Liverworts: Hepaticae.

The Mosses: Musci

The mosses are perhaps not nearly so ubiquitous as the lichens, but they make a very fair show, and they occupy unlikely, as well as favourable, ground. They do not grow actually on the surface of rocks, but the mortared crevice of the driest wall offers them foothold. We find them forming a soft fur on the tops of turf dykes, in the gravel of a path, on the screes of the hill-sides, and on the Arctic tundras. Yet it is in positions more generally suitable for plant growth, and especially where moisture is available, that they become really luxuriant. In the shelter of trees, where the shade is not too dense, our feet often sink into great cushions of hair-moss (*Polytrichum commune*). A matted vegetation grows between the cobbles of a damp yard. On an ill-drained tennis court there may be more moss than grass. Many mosses thrive in swampy places, and several grow in running streams. A notable example is *Fontinalis*, the dusky strands of which are anchored to stones, and float in even swift water currents.

Yet the mosses are true land plants, the first to show the full complement of plant-like qualities. Also they are the first plants to show the main features of higher-plant structure. By this we mean that their shoot consists of a definite stem bearing definite leaves. The hair-moss has a stem which may be a foot or more long and bears numbers of crowded pointed leaves. These are produced in three rows, though this arrangement is often not maintained in the mature plant. Mosses have no true roots. The lower end of the stem bears matted **rhizoids** which anchor it, and help in the water-supply; but these resemble the **root-hairs** rather than the roots of the higher plants.

Moss leaves are very delicate. They consist of but one layer of cells; in many species there is a midrib several cells thick which stiffens the frail structure. In some, as in the hair-moss, little plates of cells stand up from the leaf surface, extending the absorbing area. The stem is often rather complex in structure and is built up of several kinds of tissue. There is a small-celled protective skin, a large-celled

cortical region, and, in the centre, a strand of elongated fibrous cells serving at once the functions of strengthening and of transport or conduction. Here, then, we have a plant more advanced in its vegetative structure than any of the seaweeds. Yet it is far below the level of the flowering plants, for it has no root system; and its internal structure is on a simple plan. The leaves are very simple organs, and they do not bear in their axils the buds which we find in flowering plants. This means that regular branching has not yet arisen. Yet the moss is a plant which is at home on dry land and can even live in very unfavourable conditions.

How is this possible? How is it that the alga when removed from its pond withers and dies at once, while the moss survives, though its leaves are as delicate as the algal filament? There are several reasons. The first is that, through its rhizoids, the moss can draw a certain amount of water from the soil. We do not know a great deal about this aspect of the life of the moss. The rhizoid is not as efficient as a root system, yet its activity counts for something. Some mosses can meet their requirements in this way, though others must supplement the supplies from dew and rain, and some can only live in water. But we may be sure that one of the great changes which led to the possibility of life on land was the change of the rhizoid from a purely anchoring organ to one which could also absorb water. This absorbing function can only be useful if the plant has also some means of conducting the water absorbed, and this many mosses have in a primitive sort of way in the elongated fibrous cells in the centre of the stem. Elongated cells which have lost their living contents are better suited to maintain a flow of water, because they offer less resistance to the current than those which are short and lined with protoplasm. We have already noticed the occurrence of such elongated conducting cells in the brown seaweeds. There they were concerned with the conduction of food-substances, but the principle involved is the same. The evolution of water-conducting elements is the second great factor which makes life on land possible.

But perhaps the most important change of all is one which does not leap to the eye. It is the acquisition of a **cuticle** on the outer surface of the covering cells. A cuticle is a delicate coating of waxy material, and, like the waterproofing of a mackintosh, it prevents or impedes the passage of water or water-vapour. Peel an apple and leave it overnight. In the morning it is shrivelled up because it has lost so much water. The glossy appearance of the apple is due to a waxy covering so thick that it can conserve the water of the flesh for many weeks. Even when the cuticle is very thin, as it is in the mosses, it is a most important protection, without which the life of a green leaf in the air would be impossible. The formation of the cuticle is due to some

obscure changes in the fatty or waxy material of the protoplasm. It has been suggested that, when such substances meet the air on the outer walls of the plant, they congeal into a hard skin in somewhat the same way as paint dries in air, and with something of the same effect. Be that as it may, the capacity for forming this skin must have been a most important factor in the conquest of the land by water plants. The cuticle also lends a delicate tissue a certain amount of rigidity and protects it from the attacks of bacteria and of other micro-organisms.

Reproduction in Mosses

The hair-moss, and many other common species, may often be seen to bear at the tip a stalk ending in a large **capsule** or **sporogonium.** This is crowned by a curious hairy hood, the **calyptra.** When the hood is removed or falls off, the capsule is seen to have a peaked cap or lid fitting closely on the spore-box. This falls off when the capsule dries, and exposes a mass of brown spores within. In many mosses a circlet of long teeth can be seen surrounding the edge of the open spore-box. In wet weather these curve over the opening, preventing the entry of rain which would clog the spores together. In dry weather they bend back and the spores can be blown about.

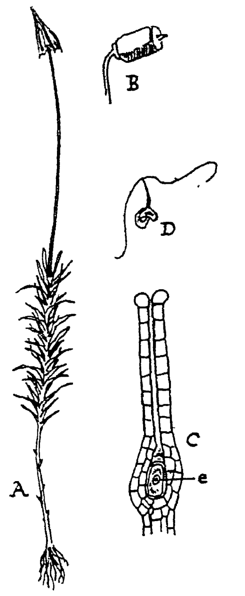

FIG. 350. *Polytrichum*, THE HAIR-MOSS

A, moss plant with capsule. B, capsule with hood removed. C, archegonium with egg-cell (*e*). D, sperm-cell.

The moss plant carries a spore-producing capsule, and one would therefore imagine it to be a spore-bearing plant or sporophyte. But this is not so. The full story of the moss life-cycle is not revealed to the naked eye. Before the development of the capsule there are to be found, usually in early spring, on the tips of the leafy shoots, groups of sexual organs. These are often surrounded by leaves differing in shape from those on the stem, so that the whole collection almost looks like a little flower. The female organ is a microscopic flask-shaped structure called an **archegonium**; in the swollen base there is a single egg-cell, while down the hollow, narrow neck the sperms must swim. It is notable that this flask-shaped archegonium is found, often much simplified, in all the ferns and conifers. It would seem to be a very satisfactory way

of nourishing and protecting the delicate egg-cell—or else these higher plants have been extremely conservative.

The male organs are called **antheridia**, and each is a hollow sac containing myriads of sperms, each bearing cilia. In some mosses archegonia and antheridia occur together, in others they are borne on the tips of separate branches, in yet others on separate plants. When ripe, the antheridium bursts at the tip, liberating the sperms into drops of rain or dew; the tip of the neck of the ripe archegonium also opens. The sperms swim about and their movements, if they come into the neighbourhood of a ripe archegonium, are directed by a chemical excretion from the neck. This chemical is simply cane-sugar. Towards this they swim, and so reach the egg-cell, which is fertilized by one of them. The fertilized egg-cell immediately starts growth and division, and from it there develops the spore-bearing capsule. The archegonium too grows for some time, covering the young capsule; ultimately it is torn away and carried up as the hood or calyptra already mentioned.

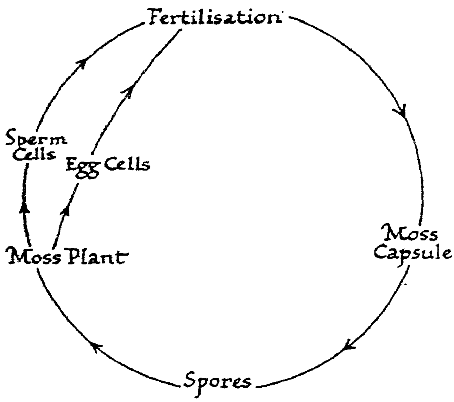

FIG. 351. DIAGRAM OF LIFE-CYCLE OF MOSS

The spores from the capsule germinate on damp soil and form, to begin with, branching filaments, very much like the filaments of an alga, and called the **protonema.** Mats of moss protonemata are often to be seen on damp soil where mosses are growing, and young moss plants may be seen springing from them; for it is from buds formed on the protonema that the moss arises.

The moss plant is thus a gametophyte, and the sporophyte generation is the capsule. This is a separate plant—and indeed it can readily be pulled away from the parent and host, on which it is but lightly fixed. It is a semi-parasite. It depends on its parent for all supplies of water and salts. It also draws most of its organic food from the moss, for, although it is green with chlorophyll, its surface is too small to be able to provide for its bulk. Here then, among the land plants, there are again alternating generations of sexual and asexual plants. *The plan established by the higher algae has been brought to land.* In the moss, too, the multitude of asexual spores serves to multiply and scatter the plant.

In its sexual reproduction the moss betrays its origin from an aquatic stock. In its male cells is preserved the mark of free-swimming ancestors. At the stage of fertilization the moss is, in fact, in a sense an aquatic, for the sperm can reach the egg only if free surface water is available. However dry and unpromising the station which the moss inhabits, at this vital point in its life it depends on the presence of water. Another remnant of algal ancestry is the protonema. The germinating spores hark back to a simple filamentous ancestor from which the higher moss visibly breaks away. Many mosses are readily propagated by small branches or fragments broken off, or set free by partial decay. Some produce special buds which become detached and start new plants.

Mosses are very rich in species. They may differ from each other in habit. There are erect forms branched and unbranched, and there are prostrate species which often form dense mats and may send reproductive branches upwards. Leaf shapes vary greatly, and there are also many differences in form, size, and structure of the capsule; but in general, the characters of the group show uniformity and the differences are for the specialist.

There is, however, one genus of mosses that is peculiar enough to deserve special mention. This is *Sphagnum*, the bog-moss. It grows most characteristically in the hollows of wet moors, where it forms extensive cushions, bright green, yellowish, or red in colour, and always soaking wet. The plants may be very long, the basal parts dying off as the tips branch and grow. If we take up a handful and squeeze it, it empties itself of water like a sponge. The capacity for retaining water is due to the peculiar structure of the leaf. Its green cells form a network the meshes of which are filled by much larger empty and colourless cells. These are prevented from collapsing by spiral thickenings of the wall, and their cavities open to the outside by pores large or small. When rain falls on the bog-moss it penetrates and fills these cells, and a store is formed within the leaf on which the plant draws in dry weather. Its vigorous growth enables Sphagnum to submerge other plants, and, on a wet hill-side, it may be seen creeping up the stems of heather. Its great water content tends to keep temperature low and to shut out air from the soil. Furthermore it has the property of setting acids free from the small quantities of salts in the surrounding water, and these acids depress bacterial action. In the soil below Sphagnum decay is arrested and plant remains accumulate. It is in this way that **peat** is formed; for peat is a deposit of undecomposed plant remains formed on the wet moors where Sphagnum, bog-cotton, and some other plants able to grow in cold, wet, acid conditions, are the chief inhabitants. In this way the bog-moss has been one of the principal agents in determining the physiography

of great tracts of country, where a poor soil and a heavy rainfall favour its growth. Incidentally its great absorbing capacity makes it a valuable dressing for wounds.

The Liverworts: Hepaticae

Placed along with the mosses in the great group of *Bryophyta* are the **liverworts** (*Hepaticae*), though many of them bear no resemblance in form or structure to mosses. A common liverwort is *Pellia*, which is often found abundantly on the wet earth along the sides of woodland ditches. It consists of a fleshy green **thallus** (p. 1052), a broad ribbon a few inches long. The thallus forks at the tip, and each fork grows on. The process is repeated indefinitely, the older parts behind dying away; this mode of growth and propagation leads to large areas of damp soil being completely covered by the plant. The thallus is several cells thick, those on the upper-side being smaller with numerous chloroplasts. Below, along the central line, masses of rhizoids grow into the soil, anchoring the plant and absorbing water. Sexual organs are borne on the upper-surface near the tips of the thallus, protected by a few scales. The **archegonia** and **antheridia** are very like those of the moss. It is a curious fact that the chemical excreted by the archegonia, which attracts the sperms, is not sugar but albumen.

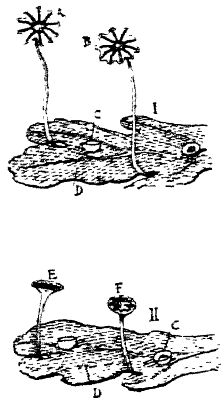

Fig. 352. *Marchantia*, a Liverwort

I, thallus (D) bearing female reproductive heads at A and B. C, a cup in which are formed small buds or gemmae which give rise to new plants. II, thallus with male reproductive heads at E and F.

From the fertilized egg-cell a capsule with stalk and spore-box grows out, as occurs in the moss. In Pellia it is formed in late autumn and lies hidden within protective scales till the following spring, when the stalk lengthens with mushroom-like rapidity, and lifts the spore-box up a couple of inches. The spore-box is simpler than that of the moss. It has no hood and no lid. It splits open into four little valves. The open capsule looks like a very small green flower with four petals. The scattering of the spores is helped by a curious arrangement quite different from that of the moss. Among the spores lie a number of long sausage-shaped bodies with spiral bands. As these **elaters** dry and get wet again they twist and untwist, and so jerk the spores about. The spore when it germinates produces a new thallus.

Pellia thus differs from a moss in the form of its **gametophyte** genera-

tion, which is on a lower level of construction than the leafy shoot. The **sporophyte** is very like that of the moss, though it too is simpler in structure. The gap between Pellia and the true mosses is bridged by some other liverworts which possess a leafy stem. These are not classed with the Mosses because their sporophyte generation is of the Pellia type. But even if we did not know of these, the life-histories in liverwort and moss are so similar that we should have to assume a relationship between the two classes. Many of the thalloid liverworts have a complicated structure. In *Marchantia* the sexual cells are borne on special umbrella-like organs which rise an inch or so from the upper-surface of the thallus. The thallus itself is more complex. It is marked out into lozenge-shaped divisions, each of which corresponds to the limits of an internal air chamber in which short filaments of assimilating cells are bathed in moist air. Marchantia, like the other thalloid liverworts, is a denizen of damp ground and may often be found on spots where fires have made a clearance and where water has afterwards accumulated. We have seen it in great vigour on the blackened heaps left by charcoal-burners in the Forest of Wyre. The leafy liverworts are frequent on the bark of trees in damp woods. They are specially abundant in tropical rain forests where they may grow even on the leaves of evergreen trees.

CHAPTER VIII

FERNS AND THEIR ALLIES (PTERIDOPHYTA)

The True Ferns: Filicales—Success of Ferns—The Horsetails: Equisetales—The Club-mosses: Lycopodiales.

THE TRUE FERNS: FILICALES

THE most obvious mark of the true fern is its great **frond.** In the familiar case of the male fern (*Dryopteris Filix-mas*), the word 'male' is a 'common' name distinguishing this species from the more delicate 'lady' fern, and has nothing to do with sex. As we see it almost everywhere in the woods, the male fern has a stout, stocky stem half-buried in mould, from near the apex of which springs a rosette of fronds each a yard high. Further back the stock is clad with the hard stumps of old fronds. Within the rosette the young fronds can be seen coiled inwards at the tip, and unrolling as they expand. Fibrous roots spring from between the frond bases. Surface moisture no longer counts for much, as it does with the mosses, for the ferns have true roots.

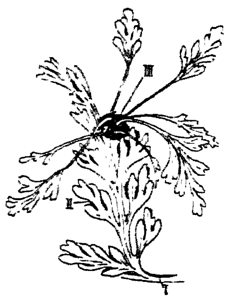

FIG. 353. FROND OF SPLEENWORT FERN
I, stalk of frond; II, groups of sporangia at the margins of the frond segments; III, young plant produced by budding.

The frond of the male fern has a stout central **rachis** with leaflets or **pinnae** on each side. It is a **compound leaf** built up on the pattern of a feather, and therefore called **pinnate.** The pinnae are in their turn divided. In many ferns the frond is very finely divided, and to this owes much of its grace. In some, as in the hart's tongue, it is entire. A peculiarity of the fern frond is the presence, especially at the base and on young fronds, of a brown, chaffy covering which may be protective in function.

The reproduction of the fern is carried out by spores. On the backs of the pinnules can be seen double rows of greenish-white patches, which, as they ripen, become dark brown or nearly black. Each grows from a little cushion above a vein, and is covered with a thin, almost round scale or **indusium,** which protects the young **sporangia** underneath. The whole patch of sporangia is called a

sorus. The numerous sporangia are just visible to the naked eye and are commonly called '**fern seed,**' although there is nothing seed-like in their nature. Each sporangium is shaped like a tennis racket, with the handle for a stalk and the head a spore-case. When the spore-case dries it bursts, and on further drying it executes a curious jerky movement which ejects the spores. These are, as usual, drought-resistant and germinate readily on damp soil. On germination a green, heart-shaped body called a **prothallus** is formed. It is about a quarter of an inch across, is very delicate, and has rhizoids growing from its lower surface. Fern prothalli may often be seen growing on the soil of fern pots in a greenhouse. On the lower surface are produced **antheridia** and **archegonia.** They resemble the corresponding organs of the moss, but they are smaller and simpler, and the archegonia are partly sunk in the prothallus. The sperm has a bunch of cilia and swims to the archegonium, directed by an excretion of organic acids. Many egg-cells may be fertilized on a prothallus, but only one gives rise to a new fern plant, which, for a time, draws on the food of its parent, but very soon becomes independent, the prothallus withering away.

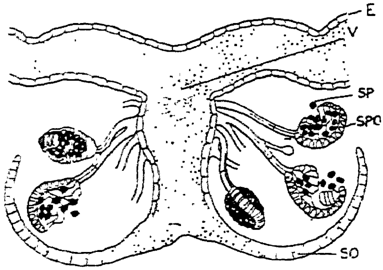

FIG. 354. SECTION THROUGH FERN FROND BEARING SPORANGIA

E, epiderm; V, vascular bundle; SO, indusium; SPO, sporangium; SP, spore.

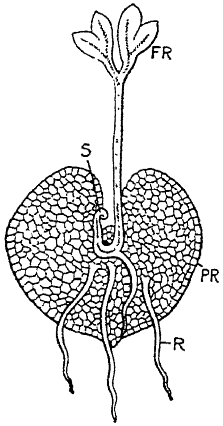

FIG. 355. FERN PROTHALLUS FROM BELOW

PR, prothallus; R, rhizoids; FR, first frond of young fern plant; S, shoot of young fern plant.

Once more we have to do with the regular alternation of sexual and asexual generations, the sporophyte producing abundant spores, which are readily dispersed, the prothallus providing for the sexual rejuvenation. Here again the traces of an algal ancestry persist in the motile sperm; and, at the same vital point as in the life-history of the moss, the presence of surface water is essential. But in one respect there is a very marked difference between the fern and the moss. The gametophyte, instead of being the prominent feature in the life-cycle, has become reduced to a tender and fugacious blade. The sporophyte has become *the fern plant,* the dominant generation. There is no doubt that this has permitted the fern to become a much

more considerable plant than the moss ever is. For the gametophyte with its motile sperms can never get far from the surface of the soil. The fern gametophyte indeed lies on the surface, and produces its sexual organs on the lower side where the merest film of water will suffice for their needs. The sporophyte, however, is free to grow into a plant the size of which is limited only by the efficiency of its water-conducting system. The advance of complexity in internal structure, and in size, which the fern shows, is a measure of the freedom it has achieved as a plant of the land surface.

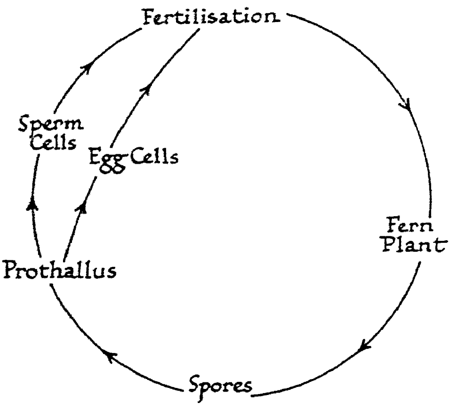

FIG. 356. DIAGRAM OF LIFE-CYCLE OF FERN

Of the internal structure of the fern we must say a little. The complexity of its tissues and the variety of its cell-forms are far beyond anything shown by the moss. If we cut across the rachis of a frond we can see a ground-mass of sappy green tissue, a sort of matrix, on which are areas of darker colour varying in shape and number from species to species. If we split the stalk we can see that these are fibrous bundles. They consist for the most part of woody tissue. The wood consists essentially of very long cells lying end to end. These cells are dead and empty of the viscid protoplasm, so that water can flow easily through them. Their walls are made strong by thick horizontal bars; the thin places between the bars are easily penetrated by the water passing from one cell to the other. The walls of the wood-cells are originally composed of cellulose, but when fully developed they are impregnated by various chemicals and so changed to **lignin** or **wood**, a change which brings with it greater strength and durability. The wall structure of the wood element emphasizes its dual use: the thick bars promote strength and the thin places penetrability by water. Wood is the *strengthening* and the *water-conducting* tissue of all higher plants.

Associated with the wood are other elongated cells, which retain their living contents and serve for the conduction of organic food back from the leaves where it is manufactured. The whole collection is surrounded by a sheath and called a **fibro-vascular bundle.** The bundles are evident in the leaves as the '**veins,**' and the ramifications of these show how efficiently the water is led to every region which

requires it. We might compare the great bundles of the leaf-stalk to the aqueducts of a town's water-supply, the midribs of the pinnae to the mains, and the fine branch-work of veins to the supply pipes of the individual houses. In the stock all the bundles from the leaves form a complicated network which gives off branches to the roots.

In the leaves great division of labour is exhibited between different cells. Special arrangements exist for the absorption of carbon dioxide, but, since the structure of the fern leaf is essentially similar to that of the flowering plants, we may omit further details here. The great new feature in the internal structure of the fern plant is the marked differentiation of tissues, and this has brought about the possibility of a really efficient water-supply which makes the plant independent of all but the soil moisture. It is the evolution of this system which has made possible the size attained by the fern and the further elaboration of still higher plants.

Success of Ferns

Unlike many very ancient races, ferns have been persistently successful, and they are represented on the earth to-day by about 6,000 species in 150 genera: in numbers they equal one of the larger families of flowering plants. They form by a long way, we should think, the most successful class among those flowerless plants that have stem, leaves, and root (**Vascular Cryptogams**). It is not merely that there are numerous different kinds of ferns, for that might be said of bacteria; it is rather that they show great variety at a high level, that they have a wide geographical range, from a sprinkling in Arctic regions to a luxuriance in the Tropics, and that they show a plastic adaptability to great diversity of habitats.

Some races of plants that were once rich in giants are represented mainly by pygmies to-day; thus there are few living club-mosses or horsetails that could be called large when compared with the extinct club-moss trees and extinct horsetail trees that formed such a conspicuous feature in Carboniferous forests, and contributed so largely to make the coal measures. But ferns have not dwindled overmuch. There are pygmies, we admit, like the tiny filmy fern or *Hymenophyllum*, still to be found in not much disturbed places like Arran in the Firth of Clyde, yet the same island shows many four or five feet specimens of the much more primitive royal fern (*Osmunda regalis*). No one wishes to make size a criterion of success, but there is an undeniable satisfaction in seeing a tree fern raising its magnificent crown of fronds fifty feet or more above the ground.

In his luminous handbook on *Ferns* (1923), Professor F. O. Bower devoted a chapter to their plasticity of habit, and we are indebted to

it here. The common male fern is typical of a large number; there is a basket-like tuft of big leaves around the apical bud of a much abbreviated stem. The oak fern shows a creeping and forking underground stem, from which at frequent intervals there arise the singularly graceful leaves. As different as possible is the vertical elongation of a stout stem, like the stately column of a tree fern like *Dicksonia*, which may be seventy feet in height. In the strange adder's tongue and moonwort, always worth searching for, there is a short, upright, deeply buried storage stem. From this there arises a single above-ground summer leaf, that dies away when autumn comes, thus illustrating one of the many ways of meeting or rather circumventing the winter.

FIG. 357. THE BRACKEN, *Pteridium aquilinum*, THE LARGEST BRITISH FERN

Just as the basket type is suited for growth in the open, the tree type for reaching or piercing the forest canopy, the creeping type for exposing many independent leaves over a large area, so we can understand the climbing and scrambling ferns as answering back effectively to difficult environmental conditions and keen competition for light and air. In the bramble ferns the scrambling is aided by bent-back prickles like those of the briar. In this country we often see the common *Polypody* growing on tree stems many feet above the ground, especially where depressions serve to catch water and a little accumulation of humus. This epiphytic habit is common among ferns in tropical forests, and there are sometimes special adaptations. Thus the growing stem may become a water store, and when it is old and dry numerous passages are formed by rupture, which serve as a welcome home for crowds of ants. They make the prepared house more convenient by cutting porches to the exterior. Very curious also are the arrangements found in two tropical Polypodies, where branches of the stock are transformed into urn-like sacs, which become filled with water during the rains and serve as a store in days of drought. They

illustrate what is called **convergence**, for they bear a striking resemblance to the urns of a flowering plant called *Dischidia*—similar adaptations to similar needs, and yet of entirely different origin, for the urns in the first case are transformed branches of the stem-stock or rhizome, those of the second case are transformed leaves.

Though many kinds of ferns grow as **epiphytes** on the shoulders of trees, there is never any parasitism. Some are helped, however, by having entered into partnership with root-fungi, illustrating what is called **mycorhiza** (p. 1092). The fungus-threads penetrate into the tissue of the fern, but what looks like an enemy becomes a friend indeed. The fungus collects from the soil the result of rotting vegetation; it works up this material, which some of the internal cells of the fern then proceed to digest. Professor Bower tells us that the young moonwort remains underground for eight or nine years, and only then sends up its single leaf, which we often find on the golf-links. During its underground life, then, the young moonwort is absolutely dependent on its fungus-partner. In the full-grown adder's tongue there is a similar partnership, but Professor Bower points out that no fern is known in which complete dependence on rotten food continues through the whole life-cycle. 'Irregular nutrition has never secured a complete hold among the ferns.'

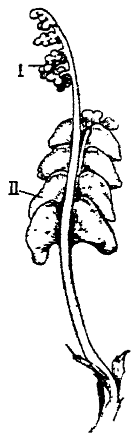

FIG. 358. *Botrychium lunaria*, THE MOONWORT
I, fertile frond; II, vegetative frond.

The majority of ferns are at home in moist and shady places, and when the moisture and shade are very pronounced there may be the special adaptation called '**filminess.**' For while there is a particular family of 'filmy ferns' (*Hymenophyllaceae*), the daintiest ferns imaginable with pellucid green leaves, the filmy *habit* is exhibited in several quite distinct groups. The 'filmies' are suited by their delicacy of structure to make the most of scanty light, and to absorb water and water-vapour readily. The filmy fern to be found in Arran has no skin and no stomata; its delicate fronds are only one cell thick. Its structure has been compared to that of a water plant living on land. Although somewhat moss-like, *Hymenophyllum* is not primitive; its simplicity is a secondary adaptation. Perhaps it is a relic of a Tertiary vegetation when the climate was moist and warm. The **hygrophytic** filmy ferns naturally lead us to those that live in swamps and marshes, or even in the water itself. There is one which is particularly at home in the muddy rice-fields, and another that is a constant companion of the mangroves on swampy tropical coasts. Our own sea-spleenwort flourishes in the niches of the shore rocks, and does not seem to thrive

if it is taken far beyond the reach of the spray. But the climax is found in the true water ferns—*Salvinia* and *Azolla*. The first has dispensed with true roots altogether, and is thus very completely aquatic; the second has roots hanging down in the water, but is, like the other, free-floating. Azolla is peculiar in always giving shelter, in cavities of its leaves, to the threads of an alga (*Anabaena*) which is also found free. This linkage may be called a **shelter-association,** for there is no evidence that the water fern derives any benefit from its companion.

And now the circle of diverse habits and habitats may be completed by noticing that a few ferns have so far departed from the typical constitution of their race that they can endure drought. Some have thick skins, others a polished, waxy surface. Some have protective scales, others a felt of hair. Every one is familiar with the wall rue which grows in the crevices between the built stones. In dry weather the crisp leaves crumble readily in our fingers, but we must not think that the plants are dead. When the rain returns, as it never fails to do, the fronds of the wall rue become glossy again.

Our survey gives a glimpse of the variety of ways in which ferns make a living, and this is of value, we think, because it illustrates one of the salient characteristics of vigorous living creatures, that they seize every kind of opportunity, and that there is no near limit to the fitnesses that may be evolved in the course of their indomitable insurgence

The Horsetails: Equisetales

The horsetails are relatives or allies of the ferns in somewhat the same way as the mosses are of the liverworts. In appearance they are very different indeed, but they have the same fundamental type of life-history, and they stand on the same level structurally. The common field-horsetail (*Equisetum arvense*), which comes up in patches in rather barren fields and along roadsides and railway embankments, has a perennial branching underground stem which easily breaks up under the spade or fork and so is difficult to eradicate. It bears swollen tubers which store food and so help to start the young shoots in spring. From this stem the green vegetative shoots rise above ground in summer. They are ribbed, and bear numerous whorls of slender ribbed branches. At the base of the branch whorl is a membranous sheath with a number of little points. This represents a whorl of leaves fused together. The work of photosynthesis is carried on by the stem and branches; the leaves have no function other than the protection of the buds. The horsetail contrasts markedly with the fern; instead of a stocky, and usually inconspicuous stem and

mighty fronds, it has a prominent and much-branched stem and insignificant leaves. Its internal differentiation is on the same level as that of the fern. Vascular bundles run up under each rib and out to the leaf-points. The stem has a central hollow and also a number of smaller canals under the furrows. These spaces seem to act as water-reservoirs. The tissues are heavily impregnated with silica, which gives the plant strength and a peculiar harshness to the touch. In country districts they have been sometimes used for scouring pots and pans.

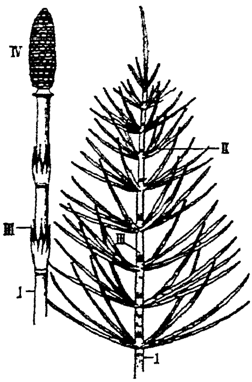

FIG. 359. *Equisetum*, THE HORSETAIL

I, main stem; II, branch stems; III, whorls of scale-leaves; IV, cone of sporangia.

This green stem bears no reproductive organs. Earlier in spring less noticeable, pale brown stems, without branches, may be seen standing about six inches high in the grass. The tips of these are covered with whorls of close-set, umbrella-like scales forming a cone. The inner (under) side of each umbrella bears a circle of sacs, which are the **sporangia.** The whole umbrella is a specialized sporangium-bearing leaf. This separation of vegetative and fertile shoots is not shown by all horsetails. Thus the delicate and graceful wood-horsetail bears the cone at the tip of its vegetative shoot. Some horsetails have a simple unbranched stem, as for example *Equisetum limosum*, the 'paddock-pipes,' which grows in stiff ranks in the mud of shallow ponds and slow streams.

The spores of the horsetails produce branching, strap-shaped **prothalli** of the same type as those of a fern. The **antheridia** and **archegonia** are borne on separate prothalli. The spores have a curious feature; attached to each there is a crossed pair of strap-like appendages which twist and untwist as they become wet or dry. It is thought that they may thus entangle with one another, and in this way secure the formation of several prothalli in close proximity; this would be useful, for the two sexes are on separate prothalli.

It will be seen that in their general features of internal structure and life-history the horsetails resemble the ferns. But they are so very different in every detail that we cannot think of them as being more than distant cousins. If the two groups arose from a common stock, they must have separated from one another in remote antiquity. Even in the Carboniferous rocks ancient members of the two groups are entirely distinct from each other.

The horsetails form a much less successful group than the ferns. There are no more than about thirty species now extant, and these

all belong to the genus *Equisetum*. They take no prominent part in the vegetation of the globe, and most attain no great size. We may suspect that here, as with the stoneworts, we have to do with plants in which a peculiarly regular type of construction has checked the occurrence of change and acted as a brake to further evolution.

The Club-mosses: Lycopodiales

There are five species of *Lycopodium*, or club-moss, native in Britain. There is also one species of *Selaginella*, a genus which is, however, better known as a greenhouse plant. None of the club-mosses is very familiar. The commonest is *Lycopodium clavatum*, also known as the stag's-horn moss, which grows amongst the ling on heather moors at moderate altitudes. Most of the others grow on the higher hills, sometimes so abundantly as to be conspicuous features of the vegetation. But they are likely to be seen only by the hill walker. In general appearance they are suggestive of coarse mosses, and this, with the club-like apical cone, has earned them their popular name. The common *Lycopodium clavatum* has a trailing stem closely set with small pointed leaves, and is anchored to the soil by slender roots. It branches frequently and the tips of the branches are erect. A big plant may be a yard or more long. On the other hand, *Lycopodium Selago* forms only an erect tuft of two or three close-set branches not more than six inches high. Club-mosses resemble horsetails in the predominance of the branching stem, and in their small leaves; the leaves, however, do their proper work. The sporangia are sacs borne singly in the angle between leaf and stem, at the tips of the branches. The fertile leaves are usually rather different in form from the others, so that the cone is sharply marked off.

Fig. 360. *Lycopodium Selago*, a Club-moss

The history of spore germination and its results was for long obscure, the reason being that the spores do not germinate till after a resting period of six years or so. They then, in many species, germinate underground and form a subterranean, tuberous prothallus. This develops with extreme slowness into a tuber which may attain the size of a gooseberry. It leads a saprophytic existence in association with a fungus. Only after a dozen years or more are sexual organs formed, archegonia and antheridia on the same prothallus. The whole life of this remarkable and unique sexual plant may be as long

as twenty years. The alternation of generations is fundamentally that of a fern, but the prothallus is unique in its structure and mode of life. In some species it lives partly above ground.

Several sorts of *Selaginella*, a genus of which we have one inconspicuous and unfamiliar *native* example, are grown in greenhouses, where they form attractive edgings under the stages. These are species from the tropics and sub-tropics, where the group is much better represented than here. They are usually very tender and require abundant moisture. Some creep on the ground, others form erect tufts, and yet others are climbers. One well-known species can resist drought, drying up and curling its stems into a close ball. These balls are sometimes sold under the name 'resurrection plant.' On being moistened they unfold and resume growth.

The vigorously branched slender stem bears four rows of small leaves, and curiously forked root-like structures. These are really branch stems which descend into the soil and there produce true roots. The sporangia are borne in little apical cones like those of Lycopodium. There are, in Selaginella, two kinds of spore, a new departure of the greatest importance. Some of the sporangia contain numerous very minute spores, and these give rise to prothalli bearing antheridia. Other sporangia produce only four large spores, and these give prothalli with archegonia. The small spores are called **microspores** and the large ones **megaspores** or **macrospores.** In all plants higher than Selaginella we find this distinction. Both types of prothallus are very small and remain partially within the spore. The male prothallus in fact consists almost entirely of a single antheridium. The female is larger, with a little mass of green tissue and several archegonia. The fertilized egg-cell gives rise to a new Selaginella plant. Here we are led a step further in the reduction in importance of the gametophyte generation, which is scarcely any longer a free-living plant.

The quillwort *Isoëtes lacustris,* which forms tufts of leaves in the water of the mountain tarns of Wales and Scotland, and a small Australian plant, *Phylloglossum,* complete the genera of the *Lycopodiales.* It is a larger and more varied group than the *Equisetales,* including altogether about five hundred species. Especially in the tropics some of its members are important in the ground vegetation of the forests. But it does not compare with the true ferns, and it is very much reduced from the vigour of its representatives in earlier geological times.

CHAPTER IX

GYMNOSPERMS: NAKED-SEEDED PLANTS

The Conifers—Big Trees or Sequoias—Some other Gymnosperms.

THE **GYMNOSPERMS** are divided into four orders:

I. **Coniferales.** The Conifers or Cone-bearers—Pines, Firs, Cypresses.
II. **Cycadales.** Cycads or Sago-palms—*Cycas, Dioön, Stangeria.*
III. **Ginkgoales.** *Ginkgo*—the Maidenhair Tree.
IV. **Gnetales.** *Gnetum, Tumboa, Ephedra.*

THE CONIFERS

Of the naked-seeded plants the conifers are much the most important, successful, and familiar. They are the only group of which we have native representatives in the British flora—the pine, the juniper, and the yew. As forest trees they cover great areas in the cooler parts of the earth's surface, reaching towards the Arctic Circle in the north, and the tree limit on the mountains, as on the Alps and Himalayas. Most, e.g. pines, firs, spruces, cypresses, monkey puzzles, are trees; a few, e.g. the junipers, are shrubs; none are herbs. The conifers are not the most modern of plant types, but they still hold their own and make an impressive show. As the source of the 'soft-wood' timbers they are of the utmost importance economically.

A pine tree shoots up as a straight sapling for twenty years or more, and then starts to bear cones. After a time it ceases to grow much in height, and branches broadly into a crown. It loses its lower shaded branches, and so comes to assume the typical form of maturity, massive, stately, and rugged, with ruddy bark and dusky leafage. The familiar needles are the leaves. They are borne in pairs in the **Scots pine,** but in some exotic species there may be bundles of half a dozen or more. When the pair of needles is pulled off, there is a little connecting-knob at the base, which is covered with chaffy scales. This is really a little branch—a *short shoot*—with a stumpy stem chaffy scale-leaves, two foliage-leaves, and an apical bud which comes to nothing. The short shoots are to be contrasted with the **long shoots,** the main twigs which go on increasing in length and thickness and bear these short shoots. These special short shoots are even better

seen in the larch, where each bears a tuft of tender leaves falling in autumn—an exceptional case in the conifers. The same short shoot bears successive crops of leaves for several years in the larch. The cedar has shoots like those of the larch, but its leaves last for several years; like almost all conifers, it is an **evergreen** tree. In the spruce, the fir, the monkey puzzle, and many others, the leaves are borne singly on the main twigs in more usual fashion. Conifer leaves are usually small; in the cypress they are almost one with the stem, only little points projecting. The monkey puzzle (*Araucaria*) has larger, tough, and sharply pointed leaves.

FIG. 361. *Pinus sylvestris*, THE SCOTS PINE

The reproductive organs of the pine are grouped in **cones,** and these are of two kinds—pollen-bearing and ovule-bearing. The pollen-bearing cones are to be found clustered at the tips of the young branches as they lengthen in spring. Each cone bears numerous projecting stamens, unlike the stamens of the flowering plants in their scale-like shape, but having two pollen sacs on their lower side. The whole cluster of cones forms a conspicuous yellow brush. The pine pollen grain is notable in having at each side a little air-filled bladder which acts as a float and assists distribution by the wind. Shake the branch of a pine with pollen cones and clouds of dusty pollen fly out. So abundant is the pollen that lakes near pine forests may have their waters covered with a sulphur-coloured dust in spring. This abundance of pollen is a mark of **wind-pollinated** plants, and the wastage is great.

The young female cone is a small, reddish-green bud borne in the place of a long shoot. One or two of these cones are usually borne near one another, each about the size of a small pea. The cones have close-set double scales, and at the base of the scale lie two ovules, little masses of tissue—the **nucellus**—each with a single covering or **integument.** The ovules are not enclosed by a carpel, but are completely naked, and

protected only by the scales on which they are borne. From the tip of the mature ovule a drop of sticky fluid exudes, and in this the flying pollen grains are caught. The pollen grain rests there for a whole year, during which the ovule-bearing cone grows into a stout, green body and turns downwards. In the following year the pollen grains send tubes down into the ovule and an egg-cell is fertilized. The egg-cell produces an embryo; the ovule becomes a seed; the cone grows larger, and its scales harden and become woody. In the autumn, or in the next summer, the scales gape apart and the seeds fall out. Each is provided with a membranous wing, derived from the scale. On this wing the seed planes to a considerable distance. Thus the maturation of the pine seed is a lengthy business.

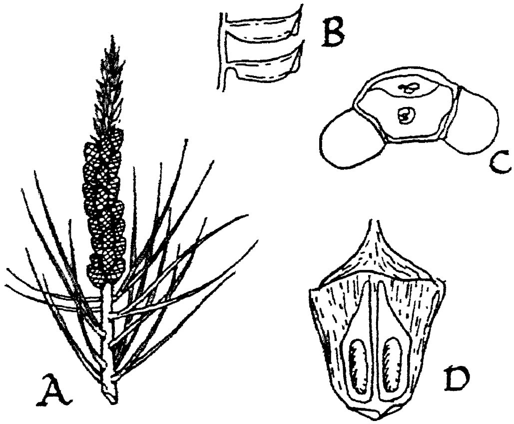

FIG. 362. REPRODUCTION OF *Pinus*
A, young shoot with male cones near apex. B, scales from male cone. C, pollen grain with two bladders. D, scale from female cone seen from above, bearing two winged seeds.

In this life-history there is at first sight nothing like the regular alternation of generations we have met with in all the lower land plants. Yet a similar cycle exists, and was revealed when the expectant eye, aided by the microscope, was turned on the intimate details of the reproductive process. The nucellus of the ovule is in fact a sporangium of the large type that occurs in *Selaginella*. It gives rise to four megaspores, but only one of these develops further. This grows in size, but never leaves the ovular tissue in which it is embedded. Within it a tissue is formed which corresponds to the female gametophyte, and at the upper end of this arise several archegonia, much reduced but still recognizable. The greater part of each consists of a giant egg-cell.

It is easy now to recognize that the pollen sac is the small type of sporangium, and the pollen grain the **microspore.** It also gives origin internally to a **prothallus,** the male plant. This male prothallus consists of only two or three little cells and an antheridium, which in its turn has only three cells: two of these are the sperms. But the sperms are naked and have no cilia nor power of movement. They are carried

passively to the archegonia, first in the wind-blown pollen, and then in the growth of the pollen tube. In the ovule a single egg-cell is fertilized and gives rise to an embryo-plant. After a time, when it possesses a definite seedling root, a stem, a circlet of seed-leaves, and an apical bud, it stops growth and dries up partially; the seed ripens and passes into a resting phase; it is detached from the parent plant and may be dispersed by the wind.

Let us note first that in this intricate history there is a repetition of the alternating cycles initiated in the algae, and maintained through all the advance of plant life on land. Let us note further that the process of reducing the importance and independence of the gametophyte, first seen in the ferns, has now gone so far that the sexual generation is scarcely recognizable. It is only by comparing the course of events in the pine with the much more obvious story of the fern that the true state of affairs becomes clear. And now we can see the importance of what has happened. The sperm no longer needs surface water to reach the egg-cell. It is the microspore which is transported, and it is transported, not by water, but by the wind; the pollen tube, a new feature, does the rest. The land plant is fully emancipated, for it no longer requires water at a critical stage of its life-history. This emancipation is emphasized by the fact that gymnosperms grow everywhere on the earth's surface, from the swamps of Florida to the tundras of the Arctic regions and from the deserts of West Africa to the heights of the Alps and the Himalayas.

With the change in the gametophyte the spores have also altered their functions. In the ferns and the club-mosses they were still the vigorously multiplying, easily scattered, asexual reproductive bodies. In Selaginella the first sign of change occurs. For with two kinds of spore, each giving rise to a prothallus of a different sex, free scattering is a thing of the past. The spores must keep together or there will be no sexual fusion. In the pine the megaspore never leaves the parent plant; and although the microspore, the pollen, is freely broadcast, the meaning of this is no longer *dispersal*. The pollen grain is freed for the sole purpose that it may *reach the ovule*. But the necessity of a dispersal stage is as urgent as ever, and it is met by the production of an entirely new body, the **seed.** We often speak of the seed as a reproductive body, but this is scarcely true in any exact sense. The reproductive bodies of the pine are still the spores in one generation, and the gametes in the other. In these the plant makes a fresh start as a single cell. The seed is rather an arrested stage in development of the sporophyte generation; a stage, too, provided with a protective coat, and often with an abundant store of food to set the seedling going. At this point separation from the firmly rooted parent takes place and dispersal can occur. Through a long course of evolution

the land plant has completely remodelled its life-story and, with the equipment with which it set out from the waters, has constructed a new type of reproductive arrangement better fitted to its life on land. The conifers are fully fledged *land plants*. Among them, indeed, we find the largest and the longest lived of all organisms, and the story of these great trees, the Sequoias of California, is so fascinating that we may well conclude our account of the order with a sketch of them.

Big Trees or Sequoias

We studied one of the two species of 'big tree' in the famous grove at Santa Cruz, about eighty miles south of San Francisco. In the early forenoon, when we had the great grove all to ourselves, it was like visiting a cathedral—indescribably impressive. Some of the living columns rise to a height of 300 feet; and not only is the stem of the main tree beautifully ridged and fluted, but it is often surrounded by daughter-trees rising from its horizontally spreading roots like secondary pillars. The basal diameter may be twenty-four feet, and the girth seventy-two; and it is not for nothing that one of the tallest is named 'Neck-breaker.' Some of the biggest are called after American giants, such as Sherman and Grant; others get their names, like 'Hen and Chickens' and 'Cathedral Group,' from the encircling of the main stem by secondary trees, often very lofty themselves. In the morning, at least, the grove was perfectly quiet; and though we saw the marks of squirrels' claws on some of the stems, we saw none in the flesh. There is dim light and delightful coolness; the ground is soft-carpeted with leaves and twigs fallen from the evergreen giants; here and there are beds of trillium, wood-sorrel, and other shade plants. But the year is still young.

Some sights turn out to be less grand than we had pictured, but this redwood grove (*Sequoia sempervirens*) surpassed our expectations, as people say. The surroundings help, for the trees rise from the floor of a very beautiful river ravine whose wooded sides make a frame for the giants. And knowledge no doubt helps, for we knew that counting the rings of wood on felled trees had proved an age of up to 3,000 years. So some of these trees were living long before Christ came! We noticed that some of the giants were placarded as 5,000 years old, but that estimate depends, of course, on an argument from analogy, which is always risky. The only way to make sure of the age of a tree is to cut it down—which Heaven forbid! On several felled stems careful counting has shown 2,400 annual rings, and a few have exceeded 3,000, with which we may well be satisfied. Writing of the other species, the big tree proper, or *Sequoia gigantea*, Dr. W. L. Jepson notes in his reliable *Trees of California* that 'when one con-

siders that the oldest logged trees were seedlings five hundred years before the Christian era, it would seem that such a lengthened period of life were sufficient to afford ample food to the reflective mind. But those popular writers, and eke the poets, whose figures are based solely upon an admiring contemplation of the bulk and stateliness of these forest giants, are not satisfied with attributing to them ages less than 5,000 to 8,000 years.'

But even if we take the well-authenticated longevity of 3,209 years, we must recognize in these Sequoias not merely symbols, but actual illustrations of the tenacity and endurance of that unique kind of activity which we call Life. Very striking in the grove was the rarity of senescence. A few giants had been overthrown by storms, for the roots are very shallow; a few had been struck by lightning, and a few severely burnt near the base many years ago by some uncertain agency; but the general impression is that of *vigorous life*. The lower branches have often gone, but the upper half of the pyramid is fresh and insurgent, bearing abundant cones which mature in their first autumn in the redwood of the coastal slopes, in their second in the big trees of the hinterland sierras. The linear leaves of the redwood arise on each side of the twig, so that flat sprays are formed; in the big tree they occur all round; and there are many other minor differences. The big tree is the more massive, but the redwood the more beautiful.

Whether the large burns are due to lightning or to friction or to man seems uncertain. The early settlers must be acquitted, in many cases at least, for the burns are too old; and though the Indians are often blamed, it has to be remembered that these children of the open do not like the half-dark, solemn groves. But the interesting biological fact is that the tree has sometimes spent a century or two in mending a great wound, slowly surrounding it with fresh growth. The bark, often a foot in thickness, is not easily kindled; and the same is true of the wood, which is without the resin canals usual in related trees. Many Californian towns are largely built of redwood, and the relative non-inflammability is obviously of great practical importance. It is worth noticing that the old San Francisco, which largely consisted of frame redwood houses, 'never had a destructive fire till 1906, when the water-supply was completely shut off by earthquake disturbance.'

In some sheltered parts of the ravine near the redwood grove we noticed oak trees smothered in lichens, some of which hung down like grey beards to a distance of over a foot—a sinister festooning—but we did not see a single lichen or moss on a redwood in the Santa Cruz grove. Another useful quality of redwood is suggested by the fact that the destructive termites or white ants are said to leave it severely alone. But this seems almost too good to be true.

Here may be mentioned the astounding fact that in one of the redwood trees called 'Giant' there is timber enough to build forty five-room cottages!

In Tertiary times there were many Sequoias, and they had several relatives, now wholly extinct, going back to the Miocene. Thus the redwood and the big tree are to be regarded as the survivors of forest trees once dominant and widespread. For unknown reasons their distribution has been restricted, and no success has rewarded man's efforts to extend it again. The extant Sequoias seem to be very fastidious as regards their environments, the big tree being confined to the Sierra Nevada, the redwood to the Californian coastal ranges.

Some Other Gymnosperms

The **CYCADS** or sago-palms are none of them native in Europe, but many may be seen in the greenhouses of botanic gardens. There are eight genera altogether, one in Asia and one in Australia, two in South Africa, and four in America; a wide distribution which indicates great antiquity. All are tropical or sub-tropical. In appearance they are much more like tree-ferns than conifers, and indeed one, *Stangeria paradoxa*, was described as a fern before its reproduction was known, and it was found to bear seeds. *Cycas* closely resembles a tree fern or palm in appearance, with its tall massive stem and its great crown of feathery leaves. The naked ovules are as large as nuts. In Cycas they are borne in notches on the edges of reduced leaves. The pollen sacs occur in numerous clusters on the lower side of large scales. The cycads are much more primitive than the conifers, and their gametophytes are not so much reduced. The sperm-cells are even provided with cilia, though they have only to swim *in the fluid within the ovules*.

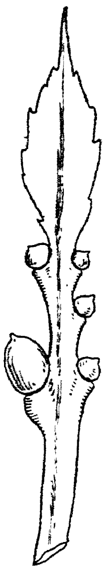

Fig. 363. *Cycas* Scale-leaf bearing naked ovules and one mature seed on its margins.

Ginkgo, the maidenhair tree, is more familiar than the cycads, being often grown successfully in gardens in England. It is a relic of a race important in the geological Middle Ages, and gradually dwindling since then. It is strange to find a whole class reduced to a single species; and even that species is no longer found wild. Ginkgo would probably have been extinct before now had it not been preserved as a sacred tree in the Buddhist monasteries of China and Japan. It differs from all other gymnosperms in the peculiar wedge-shaped

leaves. The seeds are exposed, completely naked, at the tips of twigs.

Of the remaining order of Gymnosperms, the **GNETALES**, only the little broom-like shrub, *Ephedra*, native on the Mediterranean coast and sometimes grown in rockeries, is at all familiar. *Gnetum* is a tropical climber. *Tumboa* must be placed alongside *Ginkgo* as an isolated type; more isolated than even the maidenhair tree, for it has no known near relatives either living or extinct. It grows in the deserts of South-west Africa, where it is now strictly preserved. A short clumsy stem bears two great leathery, band-shaped leaves which trail out sideways in ragged tatters. Only two leaves are produced in the course of a life which probably lasts for centuries.

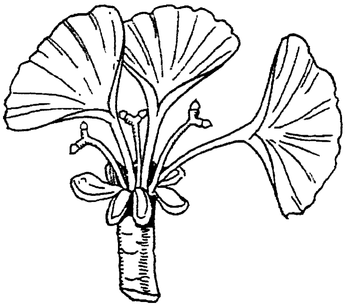

FIG. 364. *Ginkgo biloba*, THE MAIDENHAIR TREE

Shoot with three leaves and three pairs of naked ovules borne on forked stalks.

The *Gnetales* are, in their reproduction and structure, the most advanced of the Gymnosperms. Attempts have been made to prove them the forerunners of the flowering plants. But, though advanced, they seem to be on a side-line. Their peculiarities are so marked as to make it difficult to see in them the precursors of the flowering plants.

CHAPTER X

FOSSIL PLANTS

The nature of Fossils—Early Fossils—The Coal Era—The Geological Middle Ages.

THE groups we have so far described, from the mosses onward, tell the story of the conquest of the land by plants. A process of evolution has led finally in the Gymnosperms to complete fitness for life on the land surface. But we are far from suggesting that the actual succession of forms in evolution can be clearly discerned. We do not imagine that the fern has evolved from a moss, *Selaginella* from a fern, and the pine from Selaginella. These plants illustrate different floors on the great evolutionary edifice, but they do not indicate a line of descent. Indeed, some of the members of the various groups are so widely divergent from their neighbours that we may well wonder how they are related to each other, and from what stock they have descended. Our best hope of probing such problems lies in the evidence which fossils afford us of the nature of plants which covered the earth in earlier epochs of its history and are now extinct.

THE NATURE OF FOSSILS

What are fossils? No single answer can be made to that question, for fossils are of three quite different kinds. The most familiar, as they are the most striking, are the black impressions on slabs of slaty material which show the surface form of a shellfish or a fern leaf in the minutest detail. These **impressions** are the last remains of the organic material of the organism. A leaf fell in the mud and was preserved from decay: under the pressure of layer after layer of rock, exerted through millennia, the dead material changed to carbon. When the rock formed about it was split open, that carbon film still retained the form and marking of the original leaf. When masses of such leaves, stems, and other débris were compressed together, seams of coal resulted: in the case of coal the change has gone so far that no traces of the structure of the constituent material is left. The impression fossil, then, is just a carbon print of the original plant. It shows the outer

appearance, but the internal structure is largely lost, though modern methods of investigation have made something even of that.

But plants are preserved in other ways. Bits of stem, and leaf, and root, and fruit fall into water rich in dissolved material, salts of lime, or silicates, which gradually penetrate the tissues, and literally convert them into stone. These are **petrified fossils.** Masses of such material, mixed together, are found associated with coal seams, and are known as ' coal balls.' In these the external appearance of the plant is not well shown, but the internal structure may be preserved to the finest details. It would appear that the examination of the internal structure of what is in fact a block of stone would be a matter of difficulty. But it is possible to grind slices of the coal balls so thin as to be transparent, and these can then be investigated with the microscope as easily as a section of a living plant. Recently a great advance in the technique of preparing fossils has been made. A flat face is polished on a coal ball and etched slightly rough with suitable acid: a film of some such substance as collodion is poured on the surface. When this has dried it is peeled off, and carries with it a thin, transparent slice of the rock; the process can be repeated again and again so that a series of slices right through the ball are obtained.

In such a slice there is the wildest confusion of sections, and bits of section, through leaves, stem, and fruits belonging to many sorts of plants. The evidence obtained can only be sifted out with the help of great experience and skill—one might say of genius in detective work. But the information is so exact and clear that we know the anatomy of many plants which lived millions of years ago as well as we do that of the sunflower.

The third kind of fossil is the **cast.** Casts of ancient trees are the most impressive of fossils, for they give us a reliable record of the girth as well as the height of the vanished plants. They were formed by the enclosure of the plant by fine silt in which it slowly decayed, leaving only a print of its outer surfaces on the walls. Into the cavity so formed more fine silt found its way, and when this set it formed a model of the original. The process was just like the method of making a plaster cast of some solid object. Other casts were formed more directly by silt pouring into a hollow stem, and these are apt to be misleading, for the markings they show are those of the inside, not of the outside of the plant.

Early Fossils

Useful plant fossils are not found in the most ancient rocks, which yield animal remains. Débris of land plants does not accumulate in the sea, and the seaweeds are so soft that they are not readily preserved.

Only the coralline seaweeds, as we have seen, remain in rocks, helping, indeed, to form them. In Cambrian rocks there are forms which are probably algal in nature, but these are usually obscure and difficult of interpretation. In the Devonian epoch a land flora appears, and plant fossils are abundant. Among the earliest of these is a remarkable group of petrified fossils found in cherts of middle Devonian period at Rhynie in Aberdeenshire. The simplest of these has been called *Rhynia*. It consists of a creeping underground stem from which rise slender, cylindrical, branching shoots, some of which bear terminal sporangia. There are neither roots nor leaves. In structure the stem has a large-celled cortex with a protecting epidermis and a central strand of conducting woody cells. Another of these plants, *Hornea*, has hard tuberous swellings underground, and the sporangia are large and, in structure, like those of the present bog-moss. A third genus, *Asteroxylon*, has a more complex conducting strand, and its branches are clothed with leaves like those of a *Lycopodium*. In appearance, and in their sporangia, these plants rather suggest a moss. But they are sporophytes. This fact and the internal structure place them amongst the fern allies. Some, with others of the Devonian plants, are leafless, and in this they resemble the seaweeds. None have true roots—another seaweed character. Some have small leaves like those of a club-moss, and all have the conducting elements of a fern ally. They are fern allies with algal features, and may perhaps be related to the small-leaved Lycopodium stock. From later Devonian rocks there are abundant fossils with large leaves of a definitely fern-like type, and the remains preserved indicate a great development of land plants, many of which reached a large size.

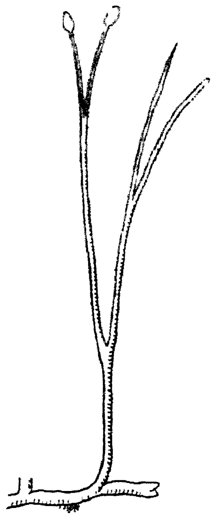

FIG. 365. RECONSTRUCTION OF *Rhynia*, ONE OF THE EARLIEST OF LAND PLANTS

Rhynia consisted of a branched stem bearing sporangia at the tips, and had neither roots nor leaves.

THE COAL ERA

In the Carboniferous era there is an abundance of fossil material, formed as impressions on the shale and petrifactions in the balls associated with coal seams. The enormous thickness of coal deposits proves the prolonged existence of a luxuriant vegetation. Perhaps

many of the plants which provided material for the deposits lived in tropical swamps, where dead remains falling in the water were compressed by layers of mud brought down by the rivers. Here we find representatives of many modern groups, along with others which are now extinct. A peculiarity of the vegetation of these days was its uniformity over a great part of the earth, indicating a climate much more even than that of to-day, and tropical where now it is temperate or frigid.

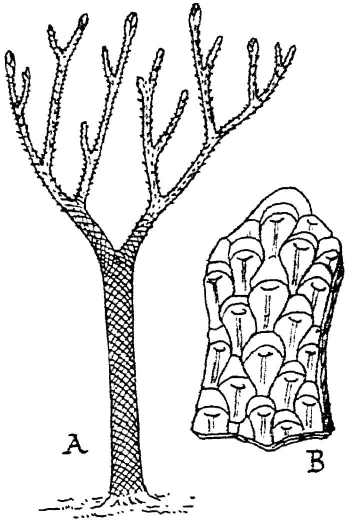

FIG. 366. *Lepidodendron*

A, reconstruction of tree. B, impressions of leaf-scars

Perhaps the chief features of the coal forests were the *Lepidodendron* trees, and their allies. They were of great height, sometimes with trunks over one hundred feet high to the point where branching begins. The total height may have reached one hundred and fifty feet. A girth of twenty feet at the base was not uncommon. The leaves were long and grass-like, covering the branches in close spirals, or vertical lines. Many of the casts of these trees show trunks from which the leaves had fallen, and the surface is set close with lozenge-shaped markings formed by the leaf bases. The Lepidodendrons were like giant club-mosses. They were more advanced than the present-day club-mosses, both in size and in their power of growing in *thickness*, a feature restricted among existing plants to the seed-plants. The sporangia were borne in great cones at the tips of the branches, on the bases of the leaves. They were of two kinds, bearing mega- and micro-spores, and in this, as also in the structure of the leaf, the Lepidodendrons resembled *Selaginella* rather than *Lycopodium*. So well preserved are some of the cones that megaspores have been observed with internal prothalli and archegonia, like those of *Selaginella*. Some species had even advanced to the production of a reproductive body of definite seed-like character. A small climbing plant, *Miadesmia*, closely related to modern Selaginellas, also produced a sort of seed. These were evidently the great days of the Lycopod stock; in numbers they were dominant, in structure they were far advanced. To-day we have, in their successors, only a remnant, reduced in importance and in complexity.

In Carboniferous times there existed in the genus *Calamites*, plants which might be briefly described as tree-horsetails. These were tall, slender trees with trunks ribbed like those of a modern horsetail, with many slender and graceful branches, and whorls of leaves larger than those of the horsetails of to-day. The cones were more complicated than horsetail cones, and produced, like those of the Lepidodendrons, two kinds of spore. Related genera had large compound leaves; and, altogether, these forerunners of *Equisetum* were a highly developed stock; but they do not seem ever to have produced seed. In more recent geological times, in the Tertiary epoch, there were fossils more like our present horsetails, but larger, and taking a more important share in the vegetation. This great line is represented to-day by only a score of species, and by none of any great size.

Impressions of fern-like leaves are probably the most familiar of plant fossils, and it has been possible to trace the history of ferns related to *Osmunda*, our royal fern, right back to Carboniferous times and beyond. The evidence of impressions is amplified by petrified remains which show structure. But we now know that many of the very numerous fern-like plants of Carboniferous times were not true ferns, because they show undoubted seeds: they are placed in an independent group, the *Pteridospermæ* or **seed-ferns.** The first of these, in which the connection of seed with foliage was established, was a plant called *Lyginodendron oldhamium*. It was, in habit, like a tree-fern, with a tall, slender stem and great leaves, divided like the frond of the spleenwort. Possibly the slender stem supported its weight of foliage by clambering on neighbouring plants with the aid of strong spines. Roots sprang from near the base of the stem, anchoring the plant in the swampy ground in which it grew. The internal structure of the stem and roots is fully known. It bore seeds, small oval bodies a quarter of an inch long, enclosed in a husk, the whole not unlike a miniature hazel nut in appearance. The pollen was formed in sporangia hanging from the edge of little umbrella-shaped scales not unlike the scales of Equisetum. The seeds have never been found actually on the Lyginodendron foliage. But as both foliage and husk bear glands of identical shape, and as the internal structure of their stalk is also the same, there is no doubt that the two belong to each other. Another seed-fern is *Neuropteris*, in which the seed has been found actually in connection with the frond. There is now no doubt that many, perhaps the majority, of the 'ferns' of Carboniferous times were really seed-ferns, and that by this time plants with the seed habit had assumed a leading position in the vegetation. True ferns also existed, and their descendants are with us to-day. But already at some earlier period, we do not know when, the great fern stock had branched, and one line had become seed-plants.

Had, then, seed-ferns no descendants? No plants quite like them exist to-day. But when we think of the cycad, *Stangeria paradoxa*, which was first described as a fern, we are led to the suggestion that perhaps the cycads are the modern descendants of the seed-ferns. The seeds of Neuropteris are definitely cycadean in character.

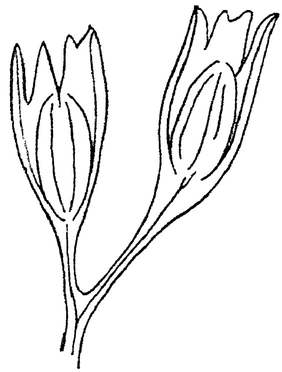

FIG. 367. *Lagenosperma*, THE SEED OF A CARBONIFEROUS SEED-FERN

Each seed is set in a cupule.

Cordaites was another seed-bearing tree of Carboniferous times, a representative of a large and flourishing family. Like Lepidodendron it reached a height of over one hundred feet, bearing a crown of branches clothed with strap-shaped leaves as much as a yard long. The fructifications were in catkins, the stamens in numerous clusters, the ovules two or three together. The structure of seed and leaf was cycadean, but the leaves, though larger, were not unlike those of the kauri pine, a conifer native in New Zealand. It is possible that Cordaites was an early representative of a stock which led to the conifers.

THE GEOLOGICAL MIDDLE AGES

To-day the cycads form a very restricted group, and in Carboniferous times—unless the Pteridosperms were precursors—they had not come into existence. But in the Mesozoic rocks, especially in the Jurassic, fossil cycads are so numerous and varied that the epoch may be said to have been an age of cycads. As the fossils have been found as far north as Greenland there is again evidence of widespread uniformity of a warm climate. Many resembled modern cycads in their stumpy stems, their foliage, and even their fructifications. Many others had reproductive organs far more complex than any known to-day. In *Cycadeoidea* the reproductive organs occurred in numerous cones set between the leaves on the stem surface. Each was nearly six inches long. The cone was enclosed by a sheath of leaves, and within these was a whorl of stamens. The stamens were in fact large pinnate leaves, folded in at the tip, and bearing innumerable microsporangia with their pollen grains. The tip of the cone was crowded with slender stalks, each ending in a single ovule. Between these stalks there grew scales whose tips widened out, and so formed a latticed roof over the ovules.

Now this arrangement is something quite new. In no modern

gymnosperm and in no ancient seed-plant are the stamens and ovules grouped together in this fashion. We have to turn to the flowering plants to find a similar arrangement. The cone of Cycadeoidea is a **sort of flower.** It even shows a degree of enclosure of the ovules not found in any gymnosperm. But it is a very peculiar flower. In no modern plant do we find such large and branched stamens. Nor are the ovules enclosed in a true fruit. The modern carpel is a leaf folded in over the ovules. In Cycadeoidea scale-leaves stand between the ovules and only roof them over rather imperfectly. Yet it has been suggested that Cycadeoidea and related forms indicate a line along which the cycads may have given rise to future Angiosperms, such as the *Magnolia* of our modern flora. *Williamsonia* is a fossil with a 'flower' similar to that of Cycadeoidea, but with simpler stamens.

Another fossil, *Caytonia*, from Jurassic rocks, is of much interest in this connection. It is an undoubted fruit, a carpel completely enclosing several ovules, and provided with a stigma. It is possible that it is the fruit of another fossil, *Sagenopteris*, though the connection has not been definitely established. Sagenopteris had a creeping stem, and bore leaves not unlike those of a wood-sorrel though much larger. Its contemporaries included shrubs and small trees of the club-moss alliance (*Lycostrobus*), seed-ferns (*Lepidopteris*), horsetails (*Neocalamites*), as well as trees (*Ginkgoites*) allied to the modern *Ginkgo*. Conifers with an evident resemblance to our monkey puzzles and sequoias also existed. It is of interest to find what appears to be a true fruit contemporary with the false fruits of Cycadeoidea. It suggests that there may have already come into existence, along lines as yet obscure, flowering plants which were to be the ancestors of our modern flora. The cycadean stock may have reached its fullest development in the trees which bore the pseudo-flowers, and then declined to its present insignificance. The flora of the secondary rocks of Jurassic times is a curious collection of ancient types with an admixture of plants of more modern aspect, but evidence of the existence of real flowering and fruit-bearing plants is scant.

Before the next great fossil-bearing strata, the Cretaceous rocks, a revolution in the plant world had taken place. The links between this period and the preceding one have been lost or have not yet been discovered. In the earliest Cretaceous deposits in this country Cycadeoidea and Williamsonia still existed along with ginkgos and monkey puzzles. In early Cretaceous deposits of other countries, as in Greenland, an entirely new flora was established; ginkgos again, sequoias, trees resembling pines and firs occurred, and, along with them, several flowering trees and shrubs belonging to modern families or genera—magnolias, breadfruits, cinnamons, oaks, planes, and poplars. The modern era had dawned, and the modern flowering plant has already

had a long history, for between to-day and that early flora of Greenland there is a stretch of many millions of years.

The fossil record of plant life has unfortunately many gaps and there is no disclosure of the beginnings of any of the great departures. In late Devonian times the land was already densely populated, but only the Rhynie fossils, and some others, give us a glimpse of plants which may have been concerned in the great change from land to water. The seed habit can be traced back at least to Carboniferous times. But these early seed-plants were already of highly complex structure, and their origin is obscure. Cycadeoidea shows us an attempt at a flower, but we cannot be sure that that attempt led to anything. Caytonia gives a tantalizing glimpse of an early fruit, but how it is related to modern Angiosperms we do not know. Suddenly in the Cretaceous deposits a modern flora appears, but its links with the past are gone. Yet though we cannot trace the direct line of descent of most modern plants, we get, by the combined study of their structure and of fossils, an idea of the lines along which evolution has taken place.

CHAPTER XI

FLOWERS, FRUITS, AND SEEDS

The flower—Pollination—Insects and flowers—Flower form and pollination -Lords-and-ladies—The story of the fig—Butterfly flowers—Birds and flowers —Fertilization—Seed-dispersal—The biology of seeds.

WE have now climbed the evolutionary ladder of the plant kingdom and reached the highest rung, that occupied by the **flowering plants** or **Angiosperms.** Let us examine their distinguishing features.

They show, of course, the differentiation into *root, stem,* and *leaf* established by the ferns. Their mode of branching, by the growth of buds in the leaf axils, is the same as that of the conifers. They have, in their largest group, the Dicotyledons, the power of increasing their girth throughout life. This power was possessed by the fossil seed-ferns, and is also exhibited by the conifers. In their internal structure, especially in the structure of their wood, they show a great advance on the conifers, for they possess true **wood-vessels,** long strings of cells opening into each other, and admirably adapted for the conduction of water. All these points will be dealt with more fully in a later chapter.

THE FLOWER

On this highest rung the most notable features are the **flowers** and **fruits.** The flower is a specialized reproductive shoot, which, in its most representative form, possesses four different kinds of members. To the outside of the flower of a buttercup there are five green scales, the **sepals,** which together make up the **calyx.** The function of the calyx is the protection of the flower in the bud. In evolution it has been derived from leaves associated with the reproductive shoot, the sort of leaf which we find, for example, at the base of the umbel of a cow-parsnip, and call a **bract.**

Then come the five brilliant yellow **petals,** making up the **corolla.** This is a landmark for visiting insects. In the buttercup each petal bears at its base a little honey-scale or **nectary,** so that here the corolla also provides the sweet food for which insects visit the flower. In other flowers the nectaries are associated with other parts, for example the floral axis.

Then come the **stamens,** summed up as the **androecium.** Each

stamen consists of a stalk, the **filament**, and a head, the **anther**. The stamen is a sporophyll bearing in its head four **microsporangia**. It is comparable to the pollen-bearing scales of the pine or of a cycad. In the flowering plant, however, the microsporangia are nearly always borne in this very definite fashion—four to each stamen. The microspores here, as in the gymnosperms, are the **pollen grains**.

Finally, the apex of the axis is occupied by a number of small green, seed-like bodies. These are the **carpels**, summed up as the **gynoecium**. When the carpels are joined together, as they are in many flowers, they form the **pistil**. Each carpel is to be regarded as a **megasporophyll** or leaf bearing the large kind of sporangium. This sporangium is the **ovule**, just as in the pine, but here the ovule is completely enclosed in the leaf which bears it. And when the ovule ripens into a seed, this too is enclosed in the leaf, which has meanwhile ripened into a **fruit**. This is one of the main features in which the flowering plants have advanced beyond the conifers. For enclosure in the carpel brings the ovule better protection and nourishment. The carpel of the buttercup bears at its tip a little rough and viscid crest on which pollen is received. This is the **stigma**, and in many flowers it stands at the end of a long stalk, the **style**.

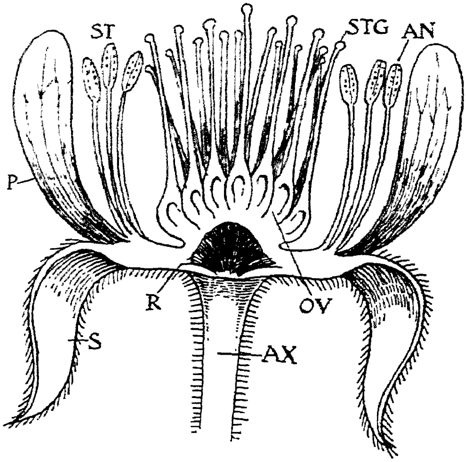

FIG. 368. DIAGRAMMATIC REPRESENTATION OF THE STRUCTURE OF A FLOWER

AX, axis; R, receptacle; S, sepal; P, petal; ST, stamen; AN, anther; OV, ovary; STG, stigma.

The carpels and stamens are comparable to the sporangium-bearing leaves of the pine, the club-mosses, or *Selaginella*. But the flower is a structure different from the cones of pine or club-moss in two definite points. It bears both carpels and stamens, whereas a pine cone has only stamens *or* ovule-bearing scales. It is enclosed by a calyx and corolla. The calyx, as we have said, has taken its origin from leaves which have become closely and permanently associated with the flower. The corolla, *something entirely new*, has probably arisen by the modification of some of the outer stamens. In the water-lily it is possible to trace the change from an undoubted stamen, through intermediate forms, to an undoubted petal. And many garden flowers,

for example the roses, owe their extra petals to a modification of some or all of the stamens. The flower has acquired an attractive whorl of leaves by sterilizing some of its pollen-bearing members.

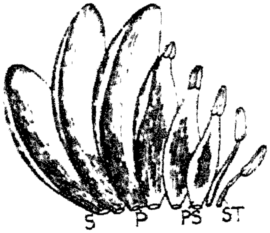

FIG. 369. TRANSITION FROM STAMEN TO PETAL IN THE FLOWER OF THE WATER-LILY (*Nymphaea*)
ST, stamen; P, petal; PS, intermediate forms; S, sepal.

The diversity in the structure of flowers is very great. We regard the buttercup type, with all its parts free from each other, and a large number of stamens and carpels, as *a primitive type*. In the further course of evolution there has been a tendency to reduce the number of parts. Thus in many flowers the stamens are regularly of the same number as the petals, as in the primrose. The number of carpels may be further reduced to two or even one. Another tendency is to join the parts together. In the primrose the sepals are all united together, as also are the petals. A third tendency is to sink the carpels in the axis of the flower, below the level of the petals and sepals, as in the apple and gooseberry. This probably brings increased protection and better nutrition. Finally, in many flowers, the all-round or radial symmetry of the buttercup is changed for bilateral symmetry. Thus the flower of a foxglove or sweat-pea can be divided into two equal halves by one cut only in a definite direction. The union of parts and the adoption of bilateral symmetry aid in hiding the nectar deeply, and in causing insects to visit the flower in one particular way, and have important effects on the way in which pollination takes place.

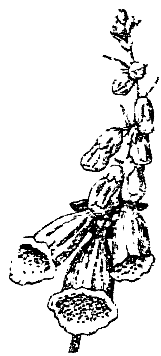

FIG. 370. *Digitalis purpurea*, THE FOXGLOVE
An advanced type of flower with united petals.

Many flowers are less complete than those of the buttercup. In the willows only carpels or stamens are present in one flower, and there is neither a calyx nor a corolla. The same is true of the hazel and the oak. Such flowers are usually regarded as having become simple by reduction from an earlier, more complex condition. But this is not certain in all cases. It is at least possible that some simple flowers are primitive, and really belong to a different stock from the others. But all flowering plants have closed carpels and bear fruits, and this is the fundamental distinction between them and the gymnosperms.

Pollination

As in the gymnosperms, the pollen must be transferred from the stamens to the ovules, or rather to the stigmas. The structure of the flower is related to this necessity. Indeed the flower, as distinct from the cone of lower forms, is to be regarded as a pollinating mechanism. There are two chief ways in which pollination takes place—by wind, and by insects.

Wind-pollinated flowers are generally of a simple type. They often lack calyx and corolla, as in the poplar and hazel, or have a reduced and sometimes hardly recognizable floral envelope, as in the grasses. No bright attractive corolla is necessary, and it would, indeed, hinder the free scattering of the pollen. The pollen is usually light and easily blown about; the pollen of a hazel is as powdery as that of a pine. The stamens often hang out of the flower on long slender filaments, as in the grasses and plantains. The stigmas are often feathery, as in the grasses and sedges Wind-pollinated flowers are frequently produced before the leaves are fully expanded. The hazel flowers shed their pollen in February. Oak and beech produce their flowers as the leaves push open the buds. In the absence of foliage the pollen dust has much freer access to the stigmas. The members of the great wind-pollinated family of the grasses and the cereals send the inflorescences well above the level of their own leaves and those of the herbs growing along with them.

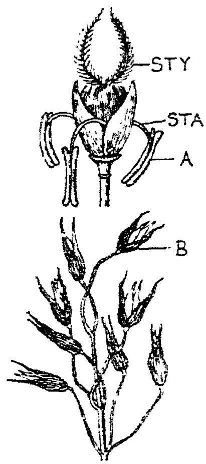

Fig. 371. Pollination of the Flowers of the Oat

A, anther; STA, filament; STY, stigma; B, ear.

One of the most impressive things about the flowering plants is the increase in the chances of **cross-pollination**, that is, the transference of pollen from the flower of one plant to that of another. The full effects of sexual reproduction can, of course, be secured only if this happens. In wind-pollinated plants there are often two kinds of flower, staminate and pistillate, and these may be borne on different plants, as is the case in the poplars. Or there may be two kinds of flower on the same plant, as in the beech and oak and hazel. Here, cross-pollination is not certain, but it is more likely than when stamens and stigmas are in closer proximity. It very often happens that the stamens and stigmas of a flower are not ripe at the same time. In the plantain the stigmas first push out through the still closed petals, and only when they have withered do the flowers open fully and the stamens shake out the pollen. In some grasses the stamens shed

their pollen before the stigmas appear; sometimes there is an interval of only a few minutes between the two events. In the hazel there are two kinds of flower on the same shoots, and the staminate catkins shed their pollen several days before the little red stigmas protrude from the bud-like pistillate catkins. In such a plant both methods of separating the sexes—in time and in space—are combined.

It is in the flowers pollinated by the second great agency, by insects, that we find the greatest variety, and, we might almost say, ingenuity, displayed in securing pollination and cross-pollination. We must emphasize the fact that nectar, colour, and scent are all related to the visits of insects. It is the possession of brilliant petals, of sweet scents, and of nectar that make up, in our minds, the *idea* of a flower. The flower, in the ordinary sense of the word, has a meaning only in relation to insect-visits. On the other hand, the structure and mode of life of many insects are possible only because of the existence of flowers. If we think of the evolution of the flowering plant on the one side, and of bees, butterflies, and moths on the other, we can often say that in a very real sense flowers and insects have made each other.

Insects and Flowers

The human eye can distinguish a red flower from a blue one, but it by no means follows that that of a bee or a butterfly can do the same. There is no doubt that bees can tell one flower from another—or why should all the bees of one sort which visit our garden fly to the flowers of the lavender spikes, and all the bees of another sort to the catmint? But that does not prove that the feature they distinguish is the colour; even to our own eye the purples of these two flowers are not dissimilar. Not many years ago an Austrian naturalist, von Frisch, was able to show that the hive-bee, at all events, can distinguish between certain colours. He trained bees to visit a dish of sugar water set on a piece of blue paper, surrounded by papers of all shades of grey, from white to black. When the sugar was removed the bees still sought it on the blue paper. Now if they were attracted by the *brightness* and not by the *colour* of the blue paper they would have mixed up the blue with some of the greys, and this they did not do.

It appears that the bee has a definite colour-sense, though not so discriminating as our own. It picks out blues or purples from yellows and oranges. But it mixes up the blues with the purples. It distinguishes, we might say, cold colours from warm colours. Also it is red colour-blind—it cannot tell red from black. This is a very remarkable discovery, for it is well known that, in our flora, there are not half a dozen true red flowers, while there are hundreds of blue and yellow.

Not only is the bee able to distinguish different colours, it can discriminate between different colour-patterns—between a blue circle on a yellow ground, and a yellow circle on a blue ground. It can also distinguish between various forms—between, for example, the many-rayed star of an aster and the four-armed cross of a gentian.

Experiment in the field has shown that these results apply also to real flowers, and that they hold not only for the bee, but also for such insects as the hover-flies and the hawk-moths. When a hawk-moth is visiting a toadflax it is flying not merely to a yellow flower, but to a yellow flower with an orange patch. The presence of the patch enables it to go straight for the entrance to the nectar-containing spur without fumbling or trials. A hover-fly visiting a grape-hyacinth is not attracted by the honeyed scent, but by the blue flowers, and it picks out easily the white spot of the petal-tips where lies the entrance to the flower. It will fly to flowers enclosed in glass tubes, which are quite visible, but quite scentless.

This is not to say that insects have no sense of smell, for the bee certainly has, and it is a sense that stands its possessor in good stead. The bee can distinguish the same sort of odours as we can, but it tends to mix up scents which appear similar to us, such as the oils of the different sorts of citrus fruits. It seems that the bee flies to colour from a distance, and at short range is guided by scent. Scent, too, is the factor which links a hive of bees with a particular kind of flower, so that we may see all the workers engaged for a whole day or longer in gathering nectar from one species.

In the great majority of cases the scent of flowers is due to an attar or essential oil, but this oil is often a mixture of several complex chemical substances, such as esters, alcohols, and ketones, which are waste-products or by-products in the life of the plant. As the chemical routine or metabolism of the living plant differs in different parts, the flower may have a fragrance different from that of the leaf. It may even vary from time to time, for it is well known that some of the orchids have one fragrance in the morning and another in the evening.

The generally accepted theory is that the odoriferous substances in flowers are not necessarily of importance in themselves, but are end-products or by-products in the breaking-down of more complex useful materials. And some of them seem to be in process of being secondarily worked up again, a method not uncommon in plants of re-utilizing waste-products—a neat method which we should call ingenious if it had been our invention. But if the fragrance should come to be secondarily of use as fragrance, then it acquires survival value and may be the subject of Natural Selection, just as it is of Artificial Selection in the case of those plants that are cultivated for scent-making.

Flower Form and Pollination

If it is for nectar that insects visit flowers, while colour and scent serve to guide their flight, it is the *form* of the flower which determines how the insect-visit shall take place, and how pollination shall occur. The great hooded sepal of the monkshood, which in this flower is coloured like a petal, conceals the spurred nectaries, and these can be reached only by a large insect like the humble-bee. Many bees may visit one flower, and some will be covered by pollen and others will carry pollen from other flowers to the stigmas. But pollen from an individual flower cannot usually of itself reach its own stigmas, for stigmas and stamens are ripe at different times. The monkshood is adapted by its flower form to pollination by one kind of insect, and its range is limited by the range of the humble-bee.

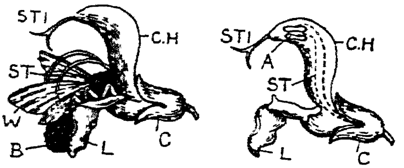

Fig. 372. Pollination of the Flower of the Sage

On the right, diagram of flower to show structure, on the left, bee visiting a flower; in pushing against the stamens it depresses them and is dusted on the back with pollen. STI, stigma; CH, hood of flower; C, calyx; L, lip which forms landing-stage; ST, stamen; A, anther; B, bee; W, wing.

Many flowers have corollas with ample landing-stages on which large insects can alight with convenience. The lower lip of the sage, of the orchis, of the snapdragon are examples, as are the broad petals of the iris, and the keel and wings of the sweet-pea. In such flowers the honey is deeply hidden in long tubes or spurs, and can be reached only by insects with long tongues—bees, butterflies, and moths. Small insects may be barred out by rings of hairs in the throat of the corolla, as in the white dead-nettle. Small insects crawl about over everything and readily cause self-pollination; but a large insect must visit the flower in one particular way. In the dead-nettle it must touch the stigma first with its back and deposit pollen from another flower, and then touch the stamens. In the orchids the masses of pollen come away on the insect's head as it leaves the flower. The bee bursts open the keel of a broom or gorse flower, and is sprayed with pollen from the stamens inside; but first the stigma has touched its body and become covered with pollen from another flower.

Flowers like those of the buttercup are wide open, with nectar concealed only by little scales. It can be, and is, sucked by short-tongued insects. But the stamens are ripe before the stigmas, so that cross-pollination is favoured. Indeed, the differential ripening of the two essential parts is extremely widespread in the flowering plants, and is often combined with some structural peculiarity which secures cross-

pollination. It seems as if the flower had gathered its two essential parts in one reproductive shoot, where their proximity makes control easy, and then separated them in time instead of in space, so that self-pollination is avoided. However, many flowers become self-pollinated late in their life if cross-pollination has failed. The great and successful dandelion family produces masses of flowers in a close head, so that the flower, small individually, is showy in the mass. The stigma is pushed on its style through the tube of the stamens, brushing out the pollen in front of it. Visiting insects receive the pollen of a flower; later visitors pollinate the expanding stigmas. But if this fails, the stigmas curl back and come in contact with their own pollen lying about the mouth of the corolla. The willow is an example of an insect-pollinated plant with male and female flowers borne on separate trees. Despite the absence of bright petals, it is eagerly visited for its nectar in the early spring.

FIG. 373. BEES VISITING MALE FLOWERS OF THE WILLOW

These are the main principles on which pollination is conducted. The variants are endless and of entrancing interest. We must content ourselves with a detailed account of one or two exceptional examples.

LORDS-AND-LADIES

An attractive hedgerow plant commoner in England than in Scotland is the cuckoo-pint or lords-and-ladies (*Arum maculatum*), with yet another name, wake-robin; though that is used in America for the white *Trillium* or wood-lily. Our Arum shows its glossy, spotted leaves, shaped like arrow-heads, very early in the year, and the flower-stalk rises in May or June, often in the shade of a wood or hedgerow. It is not so conspicuous as some smaller plants, for the flower-stalk or

spadix is enclosed in a greenish **spathe** which hides the strange flowers. In late summer, when the spathe withers, the attractive pillar of holly-berry-like fruits is very conspicuous in the tangle at the foot of the hedge. They probably catch the eye of birds that digest the juicy part of the fruit and pass out the undigested seeds. For many plants the most effective mode of seed-scattering is by having the fruits devoured!

Before we pass to the heart of the cuckoo-pint story we must notice that the glossy leaves, which look very inviting to us, are never touched by snails or slugs. The reason for the snail's abstinence becomes plain if we nibble just the tiniest piece of Arum leaf. Our lips smart painfully and for a considerable time. It is not that we are being poisoned: it is rather that we are being punctured. For the leaf is full of microscopic sharp crystals which penetrate the cells of our lips and thus produce the pain. There is, indeed, some poison in the leaf, but there is not much in a tiny fragment, and the pain that deters both man and snail from further experimenting is not chemical but physical. The underground tuberous stem contains much poison, but this disappears if the bitter juice is boiled out, or fermented out, or dried out. The residue is starch, which used to be eaten in England under the name of **Portland sago or Portland arrowroot.** With some of the sting left, the tubers were utilized in medicine, and for a considerable variety of troubles.

We see, then, that there is a good deal of character in lords-and-ladies, but the central surprise is inside the spathe.

When we open the spathe, which is an enlarged bract constricted below, we see an elongated club-shaped axis or spadix, bearing a large number of much-reduced flowers. Lowest of all there are numerous female flowers, each reduced to a simple pistil and nothing more. Above these are several rows of deterrent bristle-like projections with swollen bases. These are now known to be transformed and sterile male or staminate flowers. A third level is occupied by a crowd of stamens, which belong to numerous much-reduced male flowers, two to four stamens going to each flower. Above these, after a short bare gap, comes an upper group of bristle-like projections, which are also transformed and sterile male flowers. Then comes the cylindrical axis, which ends in an odoriferous club. We suppose that the name 'lords-and-ladies' refers to the orderly, as if processional, grouping of the males and females; but we may be quite wrong.

When the flowers are ripening they give out a nauseous odour, as if from carrion, and numerous little insects, especially the fragile moth-flies in the family *Psychodidae* and various beetles, are induced to explore the recesses of the spathe. There is also an interesting rise of temperature inside the curtain. The rest of the story is told in different

ways. Thus we used to be taught that the female flowers ripen first, and that the insects crawling about them are prevented from going up again by the lower rows of reflexed bristles. But when the male flowers ripen, the lower bristles wither and allow the insects to ascend to the stamens, where they get dusted with pollen. Soon afterwards the upper bristles also wither, and the insects get free. If they enter another, but less ripe, Arum spathe, they pollinate the female flowers. It sounds almost too good to be true, but stranger things happen. Nowadays, however, some critics have maintained that the bristles can easily be passed by insects that wish to get out, if they are not too much doped to try; and some have gone the length of saying that pollen passes from the male to the female flowers of the same Arum inflorescence.

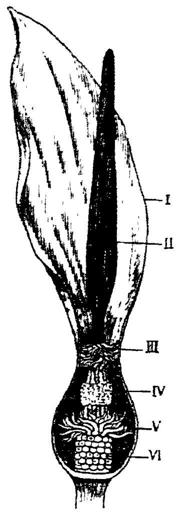

FIG. 374. INFLORESCENCE OF *Arum maculatum*, CUCKOO-PINT

I, spathe; II, spadix; III, hairs; IV, male flowers; V, hairs; VI, female flowers.

The recent careful work of Professor Knoll has cleared up some doubtful points. His studies had chiefly to do with the black Arum, which is visited by insects larger than the minute flies found in our cuckoo-pint. To test some points Knoll used accurate glass models, often with a natural club inserted. The insect-visitors are attracted by the odour of the club. The colour of the spathe is immaterial, except that strong black or white, which stands out conspicuously in certain surroundings, rivets the attention of the insects when they draw near under the influence of the olfactory stimulus. There is no warrant for the theory that the slight warmth of the spathe shelter is an inducement which prompts insects to explore.

When the attracted insect plunges into the spathe it finds itself on a slippery surface, recalling that on the upper part of some pitcher-plants, and it slides down in spite of itself into the basal enlargement. Small insects tumble through the spaces between the bristles; larger ones are intercepted and are sometimes able to fly out again. There is a sifting of the insects according to their size. The small ones that tumble through into the basal bulb cannot creep up again, for the skin surface of both bulb and bristles is too slippery, partly because of the way in which the tips of the cells are directed, and partly because of a certain oiliness. The small insects are thus imprisoned. But during the night or the day after the opening of the spathe and the entrance of insects, the internal epidermis begins to change and the slipperiness disappears.

Each basal female flower has a tuft of damp stigmatic hairs which catch the pollen grains that the small insects may have brought in from another Arum. Pollination occurs, and the stigmatic hairs dry up. During the night after opening the stamens shed their pollen, and next morning precipitate the pollen grains on the now unreceptive stigmatic hairs and on the small insects that are still there. As the epidermis of the bristles and the axis changes, the pollen-covered insects creep up past the dusty stamens into freedom, and some of them are so little impressed by the risks they have run that they proceed to another set of lords-and-ladies. They cannot resist the scent; they are led by the nose! But all 's well that ends well.

The Story of the Fig

Among the many linkages between flowers and insects none is so subtle as that between the fig and its little wasp-visitors. It is intricate to the verge of incredibility, and it has been studied since the time of Aristotle—studied to some purpose, long before it was understood!

Like many other fine things, the edible fig of the Mediterranean countries has spread from East to West. It was represented, to begin with, by the wild fig (*Ficus carica*), still to be found in some parts of Italy, and its cultivation began early in the Quaternary period. The fig was a prehistoric discovery, but it was used, as every one knows, in the Garden of Eden, and it was depicted on Egyptian walls two thousand years or more B.C. It is one out of six hundred species of Ficus, and of so much value to man that its very abundance has given rise to the expression: 'He does not care a fig.'

There is no doubt as to the origin of the cultivated fig tree from the wild *Ficus carica*, which is oftenest in the form of an open bush. The wild form has three kinds of flowers and fruits in the year, and in each case we have to deal with a hollow, fleshy inflorescence enclosing many minute flowers. When is a fruit not a fruit? When, for instance, it is a fig—since what we eat with so much pleasure and profit is the cup-shaped flower-stalk, bearing when ripe a vast collection of minute fruits, popularly called 'seeds.' Inside this hollowed flower-stalk there may be one or more of four different kinds of tiny flowers: (*a*) male flowers, usually near the opening, each with three to five short stamens producing orange-yellow pollen; (*b*) fertile female flowers, each with a single seed; (*c*) sterile female flowers, which do not produce seed; and (*d*) 'gall-flowers,' which are specially adapted to receive the egg of the little **gall-wasp,** and have no other function.

The wild fig, as we have said, has three kinds of inflorescences in the year, and one must try to keep their differences in mind. The

first crop, known as 'profichi,' is produced in spring, and consists of male flowers just below the opening, and of gall-flowers lower down. Some small female wasps (*Blastophaga grossorum*) crawl into the fig and lay eggs in the gall-flowers, one in each. The eggs develop into larvae, and these pass through the usual metamorphosis to become young wasps—all inside the minute barren seed-boxes of the gall-flowers. This shows how small the wasps must be, yet it is a credit to the fig-grower's observing powers that they have been known since the days of Herodotus. The male wasps are yellowish brown and wingless; they gnaw their way out of their cradles, and then they pierce the wall of the seed-boxes of gall-flowers in which females are still imprisoned, thus effecting insemination. This done they die.

The next event is that the females, which are winged and have a shining black posterior body, creep out of their cradle and prison, and proceed to crawl out of the ripening fig. In so doing they have to pass the male flowers, and thus they become dusted with pollen as they emerge. Although they have two pairs of wings they do not fly much, but creep about the bush seeking for the second crop of inflorescences —the summer figs.

It is now about the end of May, and the summer figs or 'mammoni' are developing. Unlike the 'profichi' they have neither gall-flowers nor male flowers, but only normal female flowers. The female wasps force their way in, but they cannot lay their eggs; on the other hand, they do something for the fig, for they pollinate the flowers. These develop seeds, and the figs become fleshy and good to eat, ripening about the end of September in Italy.

But there is a third crop of inflorescences, the 'mamme,' which contain nothing but gall-flowers. Into these 'mamme' the female wasps make their way, and an egg is laid in almost every pseudo-flower. Within their cradles the larval wasps spend the winter, and thence the fertilized female wasps creep out in spring. How firm are the knots binding fig and wasp together! All this has been about *the wild fig*; and we may, for clearness, repeat that the spring figs or profichi have male flowers and gall-flowers, the summer figs or mammoni have only fertile female flowers, and the autumn-winter mamme have gall-flowers only.

The cultivated fig occurs in two forms: (*a*) the fruit-bearer, *Ficus carica domestica*, and (*b*) the goat-fig, that bears no fruit, *Ficus carica caprificus*. Each has three crops of inflorescences, but those of the fruit-fig consist entirely of fertile female flowers, sterile in the spring crop, whereas the goat-fig bears only male flowers and gall-flowers.

The plot thickens. From the winter inflorescences (mamme) of the goat-fig inseminated female wasps escape in spring and enter the spring inflorescences of the goat-fig (profichi) and also of the fruit-fig

(' fiori di fico '). In the former they lay their eggs; in the latter nothing happens. The female flowers in the spring ' fiori di fico ' are sterile, and though the pseudo-fruits may become edible, they usually fall off.

Out of the goat-fig's spring inflorescences the pollen-dusted, likewise inseminated, female wasps escape in June, and they enter the summer inflorescences of the goat-fig and of the fruit-fig, respectively called ' mammoni ' and ' pedagnuoli.' In the former they find gall-flowers in which they lay their eggs, but there is nothing to pollinate; in the latter they find no possibility of egg-laying, but they pollinate the fertile female flowers, and stimulate the production of the most important crop of edible figs.

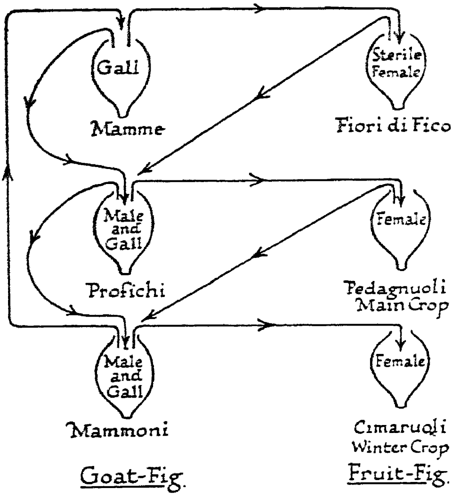

FIG. 375. POLLINATION OF THE CULTIVATED FIG

Diagrammatic representation of the various types of inflorescence; the lines with arrows indicate the movements of the pollinating wasps.

We would willingly stop here, but there is a further complication—*the third crop*. From the summer figs or mammoni of the goat-fig there emerge inseminated female wasps which do one of two things. They may enter the winter figs or mamme of the goat-fig, and lay eggs which develop into wintering larvae, to emerge as wasps next spring. Or they may enter the autumn-winter inflorescences (' cimaruoli ') of the fruit-fig, pollinating the female flowers, which alone are present, and stimulating the production of edible winter figs.

Two facts are very remarkable—the close interlinking of wasps and figs, and the origin of two cultivated forms from one wild ancestor. There is the *essentially female* fruit-fig in which the wasp cannot continue its generations, and there is the non-fruiting, *essentially male*, goat-fig in the gall-flowers of which the wasps lay their eggs. Yet these non-fruiting goat-figs are necessary for the most profitable fig-cultivation, since they produce the pollen of which the wasps are the vehicles, and pollination is the stimulus to seeding and to the best fruiting. We have to state the case cautiously, for although the custom

of growing goat-figs to ensure pollination goes back to remote antiquity, and although the Smyrna figs planted in California did not succeed until goat-figs and wasps were also domiciled there, we must admit that caprification is not practised in the north of Italy. How is this strange exception to be explained? It means that the varieties of fruit-fig cultivated in the north have become parthenogenetic, like the dandelions at our doors. But the interesting point is that while these northern figs swell up and are good to eat, they do not keep well. An ordinary dried fig is always seeded.

Finally, it may be noted that the seeds of the fruit-figs produce plants that revert to the wild-fig type; the virtues of the cultivated fruit-fig have to be continued by cuttings and grafting.

Butterfly Flowers

The gorgeous flower-stalk of the *Yucca* plant—the 'glory of the lilies'—may carry over six hundred silvery bells, each of them with numerous seeds. But everything in the way of seed depends on the visits of the female **yucca-moth,** which effects pollination by neatly inserting a ball of pollen which she has collected, thrice the size of her head, in a stigma-cup at the top of the pistil.

The moth lays its eggs in the seed-box of the beautiful bell, and immediately afterwards pollinates the pistil, so that the seed-box swells and the ovules develop into seeds, thus affording suitable soft food for the yucca-moth caterpillars that are by and by hatched out. No moth· no seeds, and no seeds no moth! As there are far more seeds than the caterpillars require, there are plenty left intact to continue the generations of Yucca. So the linkage of beauty to beauty works out well for both parties. It is a remarkably fine instance of a hand-in-glove interrelation.

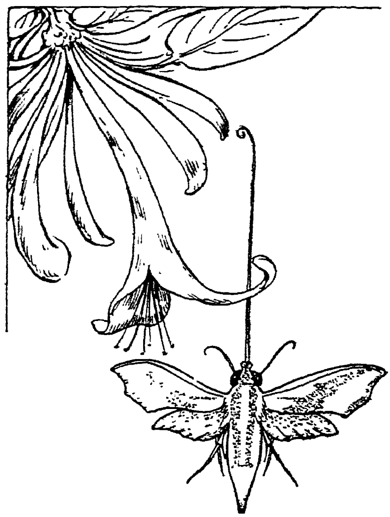

Fig. 376. Moth Visiting Flowers of Honeysuckle

For our present purpose it is unnecessary to lay much stress on the contrast between the light-loving butterflies, usually with knobbed

antennae, and the darkness-loving moths, whose antennae are usually tapering or feathery. Both are pollinators, and we may see butterflies paying visits in broad daylight to flowers like honeysuckle, pinks, orchids, and lilies. The moths seem to be more effective than butterflies as pollen-distributors, for they are more persevering in their industry—perhaps with a larger appetite as spur. Almost without exception, however, they care only for the nectar, not for the pollen at all. And here it should be noticed that in many cases feeding seems to be a very secondary consideration with full-grown *Lepidoptera*. The caterpillar lives for hunger; the butterfly chiefly for love.

Orchids are often visited by moths, especially of the hawk-moth family (*Sphingidae*), whose coiled tongue or proboscis is suited to reach down to the foot of the long tube or spur where the nectar is secreted. The arrangements by which the pollination is effected are often extraordinarily neat, and are expounded in a fascinating way in Darwin's *Fertilization of Orchids*. It is characteristic of the orchid pollen grains that, instead of being like loose dust, as in most flowers, they are tied together by microscopic elastic threads so that they form two packets or **pollinia.** When the moth presses into the orchid flower, the front of its head is made moist and sticky; and when it draws out again, it carries away the two pollen packets. They are glued on to the sticky head, one on each eye in many cases. When the moth visits another blossom of the same kind, as is the custom of these regular visitors, it lands the club-shaped pollen packet right on the proper place—the stigmatic surface of the pistil. In some species the pollen packets exhibit an automatic (hygroscopic) movement on the moth's head, bending on their stalks so that their position alters a little and becomes perfectly suited to land on the proper part of the pistil. The fitnesses are often very subtle; thus the length of the moth's tongue may be exactly suited to the length of the nectary tube in the orchid habitually visited. This is hand-in-glove, and no mistake. Some European butterflies have nectar-sucking tongues a little over an inch in length, but that of the convolvulus hawk-moth may attain to three inches, and some exotics have tongues more than twice as long! The butterfly flowers usually have pale colours, pink or cream; they often show 'honey-guides' which look as if they pointed the way to the nectar.

As we have mentioned, Charles Darwin was profoundly interested in the linkage between moths and orchids, and one cannot wonder, since both parties illustrate so well the **adaptations** which he set himself to explain. Now, he came to know a Madagascar orchid, *Angraecum sesquipedale*, which had a nectar-spur about eleven inches long. This was much longer than the tongue of any known moth, but Darwin had faith in the well-adaptedness of the world. So he

prophesied that a moth would be found with a tongue long enough to reach the feast of honey. Many years passed and at last *Macrosilius cruentius* was discovered with a tongue of ten inches!

Birds and Flowers

Several species of *Salvia*, the sage, are grown in our gardens, as for example the culinary sage. Most have blue or purple flowers, with a helmet-like upper lip protecting the stamens and stigmas, and a lower lip forming a broad landing-stage for the visiting bees. The gorgeous *Salvia splendens*, often used as an autumn bedding plant, is very different from these. The corolla, calyx, and stem-tips are all brilliant scarlet; and the flower has almost no lower lip. In its native South America this sage is pollinated by small birds, no larger than a moth, which flutter in front of the blossoms. Many exotic plants, native in Brazil, in South Africa, and in West Australia, are now known to be pollinated by birds. They differ in various ways from insect-pollinated flowers. The colour is often garish, and brilliant scarlets, yellows, and oranges are frequent. This corresponds to the colour-sense of the birds, which differs from that of insects. Birds do not see blue well, but they can distinguish reds and yellows. It is the primrose and the yellow crocus that our sparrows peck to pieces in spring in search of insects; they do not attack the purple crocus, which they probably can scarcely see.

Fig. 377. Humming-bird Visiting Flower of *Bignonia*

Birds do not settle on flowers, hence bird-pollinated flowers do not show landing-stage petals. The stigmas and stamens stand well out—as in the garden *Fuchsia*, which is another bird-pollinated flower. The nectar is usually very abundant. Most interesting is the sort of contrast with which we began, between a bird-pollinated flower and others of the same genus pollinated by insects. It suggests, what is undoubtedly true, that the bird flowers have arisen in evolution from insect-pollinated ancestors. The insect is the maker of the modern flower. Some, like the plantain, have abandoned insect-pollination for pollination by wind, and others, like *Salvia splendens*, for pollination by birds. In both cases they have undergone a transformation in their structure, losing something of their characteristic form.

Fertilization

The pollen grain germinates on the stigma and pushes its tube down through the style into the ovary. There it enters the little aperture at the apex of the integuments, and empties its contents into the **nucellus.** There are but three nuclei in the pollen tube, all that remains of the gametophytic plant. *For the pollen grain is a spore and it gives rise to the gametophyte. The nucellus of the ovule is the large megasporangium, and in it one megaspore, called the* **embryo-sac,** *comes to maturity.* In it there are ultimately present eight cells, which represent the female gametophyte. There is no longer any trace of a prothallus, nor of an archegonium. But one of the cells is the egg-cell. With it fuses one of the pollen-nuclei, the sperm-nucleus, and from the zygote thus formed develops the embryo. A new and remarkable event now takes place. Two of the cells of the embryo-sac fuse, and with them fuses a second nucleus from the pollen tube. The resulting nucleus divides and gives rise to the **endosperm.** In some plants this does not come to much, but in many it forms the chief food-store of the seed. The flour of the wheat and other cereals is the endosperm, as is the hard stony food-store of the date and the store of the buck-wheat. The endosperm is an entirely new departure on the part of the flowering plants: there is nothing comparable to it in any other group. In many seeds, however, food is stored in swollen cotyledons, as in the pea, bean, and sunflower.

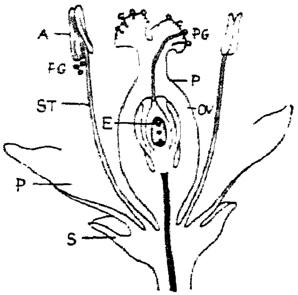

Fig. 378. Diagram of Flower to Show Process of Fertilization

S, sepal; P, petal; ST, stamen; A, anther; OV, ovary containing single ovule; P, style; PG, pollen grains sending tubes down through the style to the embryo-sac in which is the egg-cell, E.

The embryo grows till it reaches in many seeds a fair size, possessing one or two seed-leaves or cotyledons, a little root or **radicle,** and a shoot or **plumule.** When it is thus formed and has accumulated its stored food it stops growing, loses water, and passes into a resting stage as a **seed** enclosed in the toughened seed-coat derived from the integument of the ovule. Meanwhile the carpel has also ripened, sometimes drying up, as in pods and nuts, sometimes becoming fleshy, as in berries. So is the **fruit** formed. If the function of the carpel is to protect and nourish the ovule, the function of the fruit is largely to provide for the dispersal of the seed.

Seed-dispersal

A well-equipped seed's chances of life, when it is sown, are much greater than those of a spore, but there is the disadvantage, attendant on a great advantage, that even the smallest seeds are large compared with spores; and it is therefore more difficult to secure their dispersal. What we seek to illustrate here is the diversity of ways in which the problem of seed-scattering has been solved.

Before doing so let us make an elementary point clear, that for purposes of dispersal the seed and the fruit may be practically the same. The fruit is the ripe ovary or seed-box, often with addition of accessory parts, such as the top of the floral axis. The seed is an embryonic plant in a state of arrested development, often equipped with food material; and it lies within the seed-box. The anatomical distinction is clear, and yet it may be unimportant ecologically. Thus the familiar wind-borne fruit of the dandelion consists of a delicate filament with a nutlet at the base and a beautiful parachute of radiating hairs at the tip. What becomes lodged in a crevice of the soil is the nutlet-fruit, which contains a single seed. Fruit and seed are in such cases practically identical. The same is true of other nutlet-fruits, such as those of buttercups and grasses. Similarly there is a group of dry fruits (**schizocarps**) which do not open, as pods and capsules do, but divide into a number of pieces each with a single seed. In technical phrase they are *indehiscent*, yet they break into a number of **meri-carps**, each usually with a single seed. The fruits of hemlock and of labiates are of this type. What is sown is a piece of fruit, and when sprouting occurs the seedling has to find its way not only out of the softening seed-envelopes, but out of the decaying wall of the fruit-fragment.

The majority of fruits are included in the following five groups:

(1) The *box-fruits* or **capsules**, which open or dehisce to some extent when mature, and thus allow the seeds to escape. The simplest is a pea-pod or *legume*, consisting of a single folded carpel or sporophyll; the *siliqua*, characteristic of the *Cruciferae*, is built up of two carpels; the pansy fruit of three; and so on. Most complex are carpels like poppy-heads, where the dehiscence takes the form of a ring of little holes, through which the seeds tumble out. In some cases, as in the pimpernel, the lid of the capsule falls off when the seeds are ripe. The most important fact is that the dehiscence of the carpels is to be ranked beside the withering, wrinkling, and fall of foliage-leaves, for carpels are transformed foliar organs.

(2) **Schizocarps** or '*splitters*,' dry indehiscent fruits, like those of *Umbelliferae* and *Labiatae*, which divide into a number of pieces, each usually containing a single seed. Until the time of sprouting the seeds

do not escape from their fruit-enclosure, yet the fruit splits into pieces (**mericarps**).

(3) A third group of dry fruits includes the true *nuts* and *nutlets*, technically called **achenes**. They do not open to liberate the seed, neither do they split into pieces. Indeed they are single-seeded. A true nut is well illustrated by the hazel-nut, with a very hard fruit-wall to which the seed is not adherent. In the seed-like fruits of a buttercup the wall is not hard, and the seed—not very difficult to pick out—lies freely within. In the grain of wheat, the fruit-wall is rather leathery, and the seed adheres to it. In such cases fruit and seed are practically identical; what is sown is the fruit.

Among the *soft fruits* there are two main types: (4) the *stone-fruits*, like cherries and plums, and (5) the true *berries*, like gooseberries and grapes. In stone-fruits the hard part or 'stone' is the third and innermost layer of the fruit, the *endocarp*, and the pulp is the middle layer or *mesocarp*. Inside the stone the familiar kernel is of course the seed. In true berries, on the other hand, the hard part is the wall of the seed; and the pulp of the fruit often contains several seeds. It is interesting, though not relevant to ecology, to think out some of the difficult fruits; thus it seems that a coco-nut is a stone-fruit in which the pulp is represented by the fibrous layer used in making mats; and that the walnut is a stone-fruit, for outside the familiar stone or nut there lies the firm fleshy middle part used for pickles and corresponding to the juicy part of a peach.

Berries are soft fruits without a hard endocarp (innermost fruit-wall), but with tough coats to the seeds which lie embedded in the pulp. Even ecologically it is of some importance to understand clearly that the seed of a cherry, let us say, is inside the hard stone of the fruit, whereas the hard bodies inside a grape are the seeds, which have very strong envelopes. A gooseberry is a typical berry, but there are some difficult forms, such as oranges, where the hard seeds are embedded in the centre of a pulp composed of much-enlarged juicy cells. Even more difficult is the date, where the seed inside the fleshy pulp has nutrient tissue (endosperm) of almost bony hardness.

MODES OF DISPERSAL.—There are five main ways in which seeds (or fruits in certain cases) are scattered: (1) by the wind, (2) by water currents, (3) by explosive dehiscence, (4) by attachment to animals, and (5) by being swallowed by animals.

(1) Dispersal by means of the wind is well illustrated by dandelion-down and thistle-down and the like, where the nutlet-fruit, containing a seed, is wafted by the wind, often for great distances. The world-wide representation of the ragwort genus (*Senecio*) is in part associated with the effectiveness of the fruit's parachuting, due to the development of a tuft of hairs (**pappus**) on the top of the nutlet or **cypsela**.

The fruit of the clematis or traveller's joy is a nutlet with a feathery plume on its tip, the hoary appearance of the crowded plumes giving origin to another of this favourite plant's many names—old-man's-beard. When many fruits are simultaneously set free by the breeze, the plumes are often entangled in long lines, which float away with a beautiful wavy motion, like silver serpents in the air. The dispersal of the linked fruits may be followed for many yards; but gradually the links are broken. Even then each feathered achene continues to be wafted until it fortuitously sinks to earth, and is more or less fortuitously moored. Unfortunately for man, many 'weeds' are effectively spread by this parachuting adaptation.

In some cases the parachute takes the form of a light wing-like expansion, as in the maple, and this brings about a whirling oblique movement when the fruit is wrenched off by the wind. By its gyrations the fruit is borne beyond the shaded zone round the parent tree. The frequency of short-distance parachuting suggests that it is as important as a long journey, but it is, of course, more readily attained. It is particularly common in trees such as maple, ash, and elm. From the ecological point of view it is almost immaterial whether the parachuting apparatus is carried by the *fruit* or by the *seed*; both arrangements are common. Hairs are attached to the seeds of the cotton-plant (*Gossypium*) and of the willow-herb (*Epilobium*); a wing is attached to the seed of the pine, but to the fruit of the sycamore.

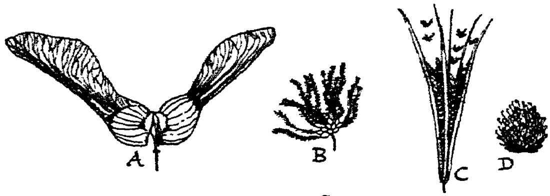

FIG. 379. FRUIT- AND SEED-DISPERSAL
A, winged fruits of maple. B, plumed fruits of clematis. C, plumed seeds of willow-herb. D, hooked fruiting head of burdock.

An unusual mode of dispersal is illustrated by some desert plants, which break off from their roots when mature and are driven by the wind along the ground, liberating their seeds as they go. Such are the American tumbleweeds and pigweeds, which illustrate in an interesting way how a desiccation natural to the habitat may be turned to an advantage in dispersal. The glasswort (*Salsola Kali*)—one of the goosefoot order, *Chenopodiaceae*, but often called the Russian thistle—shows the same habit of detachment, and has of recent years become a serious agricultural pest in North America. In the rose of Jericho (*Anastatica hierochuntica*), a crucifer of the Mediterranean region, the leaves fall off in the dry season, when the seeds are ripening, the branches fold together, and the whole plant breaks off. It is driven about like a light ball by the wind. But the pods remain closed till it

reaches moisture or the rains return. Here may be mentioned the fruit of the porcupine-grass (*Stipa*), which has a long spirally twisted awn. The awn is very hygroscopic, untwisting in moisture, coiling again in drought; and these changes enable the fruit to creep on the surface of the ground and to bore into crevices. The 'animated oat,' sometimes listed by seedsmen, shows the same thing, though its awn is of a different nature. The stork's-bills and crane's-bills among the dicotyledons have this method of dispersal and burial; indeed we may study it at home if we allow a house geranium (*Pelargonium*) to ripen its fruits.

(2) Many truly aquatic plants, such as pondweeds and water-lilies, have their seeds or fruits normally distributed by water currents. In adaptation to this mode of dispersal there is often a resistant outer coat which prevents the premature entrance of water, and there is often a layer of air cavities which secure flotation. The coco-nut can be carried by oceanic currents, and is widely distributed on inhabited islands in tropical seas. Its home is uncertain, but there is some evidence for the Magdalena valley in the north of South America. There has been a tendency to exaggerate the coco-nut's adaptation to dispersal by water. But the hard waxed epicarp keeps the water out; the fibrous mesocarp makes the fruit buoyant; the thick stone or endocarp prevents injury to the seed when the fruit is battered on the shore; the milk supplies fluid enough to keep the washed-up nut supplied till it can sprout and send its root below the surface salt into a freshwater layer of soil. It must be admitted, however; that while coco-nuts are often found among the jetsam of oceanic islands, they are very rarely known to sprout; and they are not known to survive unless man looks after them. Yet it may be that successful sprouting occurs when exceptional tides or storms land the nuts far above the usual tide-mark. It is certain that the resilient husk serves to protect the delicate seed from injury when it falls from the top of the tree where it is borne.

Familiar in greenhouses is a Madagascar aquatic plant, *Ouvirandra*, in which the submerged leaves become penetrated by a multitude of meshes between the veins, and look like skeleton leaves. In reality this effects a great increase in the surface available for gaseous exchange. Resistance to water currents is also diminished. It is noteworthy that the same feature is shown by certain of the kelps—a fine instance of convergence in evolution. In *Ouvirandra berneriana* there is a strikingly adaptive mode of dispersal. The fruit bursts explosively, and the buoyant seed floats on the surface, where it rapidly germinates. As it gets free from its wrappings it sinks to the floor of the stream, and is at once ready to effect root-attachment. This unusual sprouting while free-floating probably reduces the risk of being washed away or

driven on to the land. Many of the mangroves on the tropical shore effect the same by being viviparous; that is to say, germination actually comes about while the fruit is still hanging on the parent tree, and what drops into the swamp is a young plant dibbling itself in before it can be swept away to the sea.

(3) The drying-up of the carpels composing a dry seed-box, analogous to the withering and fall of the foliage-leaves, allows the seeds to tumble out; and this commonplace dehiscence leads on by gradations to ruptures sometimes sensational in their explosiveness. Every one is familiar with the little popgun explosions of the broom-pods on a sunny autumn day, by which the seeds are catapulted out to a distance of several feet. There is nothing vital in this, for it is entirely due to the unequal shrinkage of dead cells in the wall of the drying pod. But this is not the case when a touch sets free the five valves of the balsam, whose expressive name of 'touch-me-not' (*Impatiens noli-me-tangere*) refers to its ready explosiveness. At a touch the ripe valves roll up like springs, and send the seeds flying; but the force in this case is due to the turgid living cells in the walls of the fruit. The extreme case is the sandbox tree (*Hura crepitans*), where the drying fruit explodes with a noise like a pistol-shot, and shoots the seeds for a few yards. Explosive fruits are not necessarily dry, for the squirting cucumber of Italy first frees itself from its stalk and forces out the fluid contents and the seeds through the hole thus formed. A very extraordinary analogous case is that of the unique Californian mistletoe, which may shoot its seeds for several yards on to an adjacent branch.

(4) Many fruits are covered externally with hooks or roughnesses which cause them to adhere to passing animals, as is well illustrated in burdock, goose-grass, medick, hound's-tongue, and cocklebur. After a time the external passengers fall off, it may be miles from the place where they became entangled. Darwin called attention to a frequent variation of this method, when birds carry seeds in the mud-balls which are formed on their feet or shanks. Let us cite again his most famous case, discussed in the *Origin of Species* (1859): 'Professor Newton sent me a leg of a red-legged partridge (*Caccabis rufa*), which had been wounded and could not fly, with a ball of hard earth adhering to it, and weighing six and a half ounces. The earth had been kept for three years, but when broken, watered, and placed under a bell-glass, no less than eighty-two plants sprang from it: these consisted of twelve monocotyledons, including the common oat, and at least one kind of grass, and of seventy dicotyledons, which consisted, judging from the young leaves, of at least three distinct species. With such facts before us, can we doubt that the many birds which are annually blown by gales across great spaces of ocean, and which annually migrate—for instance, the millions of quails across the Mediterranean—must

occasionally transport a few seeds embedded in dirt adhering to their feet or beaks? '

The last word suggests the peculiar case of the mistletoe and the missel-thrush. For while the missel-thrush often succeeds in swallowing the glutinous berry outright, and may void the undigested seed on some distant tree, what we are sure of is that the ordinary planting of the mistletoe occurs when the missel-thrush wipes from its beak a seed enclosed in the viscid pulp which it has failed to swallow.

(5) A somewhat paradoxical way of securing dispersal is to be swallowed by bird or beast, the success depending on the fact that the seed may be ejected from the mouth or the crop or may be voided from the food-canal before digestion has occurred. In this way the seeds of some of the stone-fruits and many of the berries are scattered. In this connection there may be some advantage in conspicuously coloured fruits, yet it must be noted that many birds seem to be colour-blind to bluish tints. Moreover, many palatable fruits are inconspicuous. In all probability the frugivorous bird's individual experience and association-forming counts for much. Large 'stones' are seldom swallowed; small seeds are sometimes digested; yet on the whole it seems justifiable to say that many seeds are scattered by being swallowed by birds and mammals.

Besides the methods of dispersal which we have mentioned there are others of minor importance, but of much interest. Thus some ants in carrying certain fruits to the nest lose them by the way; squirrels forget some of the nuts they have hidden; earthworms plant the seeds of various trees.

For distant dispersal the most important agent is undoubtedly the wind; but in the case of oceanic islands the water currents are even more important. Fifteen years after the Krakatoan eruption had killed off all the plants on the island (1883), fifty-three species of seed-plants had established themselves. Of these, 60 per cent, chiefly shore forms, were carried by ocean currents; 32 per cent by the wind; and 8 per cent by animals.

The Biology of Seeds

In some of the higher animals, such as the badger, the fertilized egg-cell develops for a time into an embryo, and then stops for a long rest. Among the lower animals, also, this resting is not uncommon, and in the plant world it is particularly characteristic of seeds. They develop up to a certain point, and then they stop, and do not begin again till they are getting ready for sprouting. It is natural enough that there should be a resting time after a period of development—life has many

of these see-saws—but the quiescence may be thought of in other ways as well. Thus it might be very disadvantageous if the embryo-plant grew too big for the ovule or for the seed-box; and we must not too hurriedly say 'Impossible!' for the embryo of the mangrove tree develops so vigorously inside the fruit that it protrudes and falls off into the seashore mud. This works well for the mangrove, but it would be ruination to most plants. It may also be that after the ripening of the fruit and the withering of the flower there is little food available for the seeds.

In any case it seems good sense to say that, for most plants, those kinds have succeeded whose seeds passed into a state of **arrested development.** This made it possible for the seeds to wait till the season was suitable for sprouting, or till they were sown in a suitable place. No doubt there are some seeds that usually germinate without a long rest, as in the case of willows, crucifers and cereals; but it seems safe to say that for most plants it is advantageous that their seeds should be able to lie low for a considerable time. It gives the seeds increased chances of life if there is no need for hurry, if they can simply wait for spring, or until they are carried to a more suitable place. And if the embryo-plant can wait in a state of arrested development, that makes it more possible to have very protective envelopes and a very condensed and hard legacy of food.

If it be said that the embryo-plant *simply has to lie low* because of the hardness of the surrounding tissue and the seed-coats, and because of the unsuitable soil and weather, the answer is that this is not always confirmed by the experiments of artificially removing the hard envelopes or of sowing the seeds in artificially hospitable conditions. Moreover, some seeds germinate best after more than one winter's dormancy. There seem to be deep advantages in a prolonged 'lying low.'

TENACITY OF LIFE IN SEEDS.—Among the many errors that die hard is the sprouting of 'mummy-wheat.' Man dearly loves a touch of the magical, and he is unwilling to give up the picturesque belief that wheat from inside a mummy-case may sprout after thousands of years of dormancy. There is the story of the man who bought some 'mummy-wheat' in Egypt and sowed it in Australia, where it germinated and grew with great vigour. There are many such 'records,' but in every carefully conducted scientific experiment the true mummy-wheat has refused to sprout at all. What happens in the ordinary popular experiments is the sprouting of *faked* mummy-wheat, that is to say, of modern seeds substituted for the ancient ones. The supply has to meet the demand; and we have heard that the alleged mummy-wheat sometimes grows into a variety that was not known in the time of the Pharaohs, but evolved in the early twentieth century. In any

case it may be safely said that if mummy-wheat germinates, it is not true mummy-wheat. So that 's that!

On the other hand, there is no denying that seeds may remain alive for many years. Thus, Becquerel proved that some seeds germinated after resting for eighty-seven years in a herbarium—a *hortus siccus* indeed! As regards the sensitive plant, a dormancy of sixty years has been demonstrated, and the Indian Lotus has been known to germinate after having lain dormant for at least one century and perhaps for four centuries. In most cases, however, a tenth of that period would be considered a long dormancy. Different kinds of seeds differ in their power of lying low, and much may also depend on the nature of the medium in which they lie. It has often been noticed that the re-digging of a forsaken cottage garden is followed by a reappearance of old-fashioned flowers that had not been seen there for years; but care must be taken to show that the reappearing flowers came from seeds that had been lying dormant and not from underground stems or the like which were stimulated by the exposure. Allowance must also be made for the possibility of some fortuitous fresh sowing, e.g. of seeds included in the manure dug in, or of seeds carried on to the freshly dug soil by the wind, or on the feet of birds.

PROTECTIVE HUSKS.—Seeds normally come to an approximate standstill in their development, being in a state of arrest when they are liberated; the quiescent state may be prolonged after sowing, sometimes for a considerable period in natural conditions, or for a still longer period in experiments. Yet a little more must be said in regard to the frequent insusceptibility of seeds to untoward external influences. This is familiar in Nature, where seeds often land in very unsuitable places, such as little crevices in a wall, and yet do not die; and more striking data have been furnished by experiments—by those of Becquerel in particular.

The life of the embryo within the seed is anything but assertive, and yet it is strangely tough. One reason may be found in the seed-envelopes, which allow of little diffusion as long as they are dry. Becquerel fitted pieces of the tough seed-coats of peas and beans on the top of a tube of mercury, above a Torricellian vacuum, and found that no air was drawn through, even in the course of months. The seed-envelopes are gas-proof, as long as they are dry. When they are soaked in water, however, they show the gaseous absorption that one would expect.

In other experiments Becquerel showed that, in addition to the insulating seed-coats, there is extraordinary resisting power in seeds themselves. He perforated the envelopes of the seeds of wheat, mustard, and lucerne, and subjected them to very inhospitable conditions without robbing them of their capacity for sprouting. Some

of the trials which they withstood were extraordinary. He dried them in a vacuum at 40° C. for six months; sealed them up in an almost exhausted vacuum tube for a year; submitted them to the temperature of liquid air (−190°) for three weeks, and of liquid hydrogen (−250°) for three days; after which he put them on moist cotton-wool—where they germinated as usual! Becquerel concluded that there was a complete cessation of the kind of activity we call 'life'—which implies on its chemical side the downbreaking and rebuilding of proteins and other complex carbon-compounds. It is difficult, however, to call a seed 'dead' if it can eventually sprout. All that we can say is that seed may lose all sign of life without really dying.

CHAPTER XII

ILLUSTRATIONS OF FAMILIES OF FLOWERING PLANTS

Monocotyledons and Dicotyledons

THE flowering plants are divided into the two great groups of Monocotyledons and Dicotyledons. These are distinguished primarily by the number of their seed-leaves, but they have many other differences. The Monocotyledons are predominantly herbaceous and have only one great tree family—the palms. Many produce bulbs and corms. The Dicotyledons include many herbs and also many trees and shrubs. The Dicotyledons have the faculty of growing in thickness by a **cambium** throughout their lives. In Monocotyledons the power of growth in thickness is absent, or much restricted, and, when present, is not due to cambial activity. In the Monocotyledons the leaves are often narrow, as in the grasses and daffodil, and their veins run parallel to one another. Many Dicotyledons have broad leaves and the veins usually form a network. The parts of the flower are usually in threes in the Monocotyledons and usually in fours or fives in the Dicotyledons. The two groups are thus very distinct, and it is at least possible that they belong to entirely separate stocks; they certainly diverged from each other at a very early date.

Within these two great groups the flowering plants are classified in families in the way we have already described. In the Dicotyledons it is now customary to recognize a distinction between two classes called the Archichlamydeae and the Metachlamydeae. The class of Archichlamydeae includes those families with the simpler type of flower, in which the parts are free from each other: the flowers are often lacking in complexity. The latter includes families of an advanced type, in which the flowers have united parts. Botanical evolutionists are usually of opinion that these metachlamydeous families represent the higher stages in the evolution of the flowering plants; at their head we place the daisy family, the *Compositae*, the largest family in species and individuals and the most highly evolved of all plants.

We wish to attempt to indicate some of the variety of the flowering plants by a brief description of a few families. We cannot be exhaustive or even representative, for in species the flowering plants number over a quarter of a million and there are some three hundred families.

MONOCOTYLEDONS

Liliaceae. The tulip is a good example both of this family and of the monocotyledons in general. It is a bulbous plant sending up broad leaves with the parallel veins of the group. The stem usually bears a single flower and this has all its parts in threes. Calyx and corolla are very similar and are included in the term **perianth.** Within this there are six stamens. The gynoecium consists of three carpels united together with three stigmas on top. A section through the ovary shows three compartments, each with many ovules set along the centre wall. The ripe fruit splits open by valves which secure the liberation of the seeds. It is a simple, straightforward kind of flower.

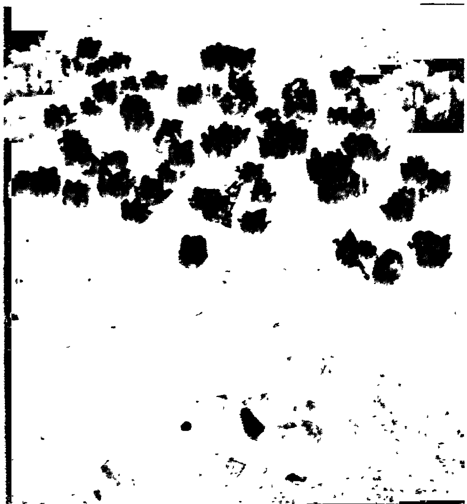

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FIG. 380. A CLUMP OF DARWIN TULIPS

Like many other good things, the tulip came from the East, the home of the genus being the uplands near the headwaters of the Euphrates and Tigris. Though one or two species are probably true natives of Greece and Turkey in Europe, tulips were not cultivated in Western gardens till the sixteenth century. The so-called wild species of the Near East, like the *Tulipa silvestris* found even in England, are introductions from about the same date. It was as an already cultivated plant that the tulip was brought to Europe, probably from Persia or Iraq, but, as must be said of so many garden plants, its wild ancestor is uncertain. It is probably right to use the word ' ancestor ' in the singular, for all the garden tulips are fertile with one another, a fact which points to a single origin. It was in 1593 that an ' excellent man,' Carolus Clusius, came to Leyden as Professor of Botany and brought back with him, originally from Constantinople, as part of his stock-in-trade, a number of tulips. He asked so high a price for them that he sold none, but by a lucky chance they were stolen, and soon began to spring up in all sorts of unexpected places such as London. We do not wish to convey the impression that Clusius introduced the tulip from the East, for he

himself speaks (as Sir Daniel Hall tells us) of an Antwerp merchant who had previously received some of the precious bulbs from Constantinople and had mistaken them for onions. Cooked tulips, eaten with oil and vinegar, surely make one of the quaintest of gastronomic adventures! But the important fact is that tulips 'caught on' in western Europe early in the seventeenth century, and that they were 'made garden flowers' from the very beginning. 'Made,' yet far from finished, for the tulip is a fountain of changefulness, and to its varieties there is no end. The 'tulip-grower' to the Grand Vizier Ibrahim Pasha, who was in office from 1728 to 1730, enumerated no fewer than 1,323 varieties, describing seventy-four in full. We do not know how the list stands to-day, but it is not stationary.

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FIG. 381. SNOWDROPS

The Western enthusiasm for tulips which marked the first half of the seventeenth century rose to a pathological intensity. Over £300 might be paid for one bulb, with a carriage and pair thrown in to the seller. From 1634 to 1637 there was a 'tulip mania' in Holland; 'all classes of the people entered into the gamble, in which bulbs were sold and resold for a rise while they were still in the ground.' On the whole it was a sorry spectacle, for the enthusiasm was neither aesthetic nor scientific, and it did not lead to any notable improvement of the tulip. As Sir Daniel Hall says: 'The whole affair grew out of the passion for speculation which affects all men in times of prosperity, such as a couple of generations later gave rise to Law's projects in France and the South Sea Bubble in England.' We must, however, draw a distinction between the 'tulip mania' and the still persistent search for promising new departures, for which £100 may not be too much to pay.

Why are tulips such favourites? Partly, we suppose, because of their fine colours, which often attain to a fascinating purity of scarlet, crimson, orange, yellow, and white. The long stalk that lifts the cup is gracefully proportioned, and the leaves are not too fleshy. There is a pleasing quality in the contours of the fully formed flower, and even its disarray, when past its best, has a charm. Every one likes to look into the cup, as if surprising a secret. But the fact is that we do not know why we like tulips so much. There is, no doubt, the strictly aesthetic emotion — a thing of beauty is a joy for ever — but there is more. Perhaps when the plot of brown earth becomes transfigured in a short time into a gay crowd of turbaned heads, we get a welcome reminder of the power life has of conquering things.

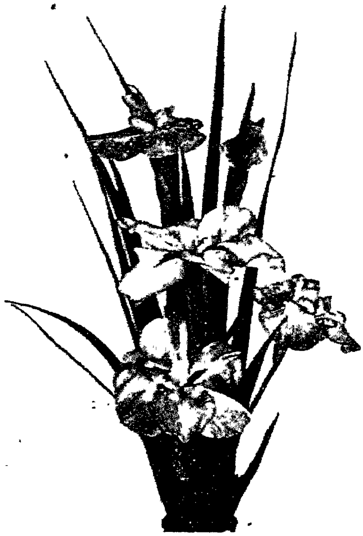

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FIG. 382. IRIS KAEMPFERI

Exactly the same floral structure is exhibited by the lily, Solomon's seal, hyacinth (which has, however, united petals), and *Colchicum* or autumn crocus. 'Crocus' is a misnomer, for despite a superficial resemblance in the flowers, the crocus does not belong to the same family. There is then a great variety of growth habit, for the family (*Liliaceae*) includes bulbous plants, plants with underground stems or **rhizomes** like Solomon's seal, scramblers like asparagus, shrubs like butcher's-broom, and even small trees of peculiar appearance like some of the big Aloes and the grass-trees of Australia. All these are united by a common floral structure.

Juncaceae. We place the rushes near the lilies, for the little brown flowers, conspicuous only because they are produced in dense heads, and never showy, are nevertheless lily-like in structure. There are two common genera. The true rushes (*Juncus*) are plants of marshy ground. Their tufts in low-lying fields proclaim the need of drainage. The stems and leaves are often alike, slender, cylindrical, pointed, hollow, and filled with a white pith, which in our young days was stripped and dipped in a 'crusie' of oil to serve as a night light. The hollow pithy stem is an air passage to the roots which, living in water-logged soil, stand in need of aëration. The wood-rushes

(*Luzula*) have grassy leaves, and are often abundant in pastures and woods.

Amaryllidaceae: Snowdrop family. The flower of the snowdrop is distinguishable from that of the lily in having petals which differ in shape from the sepals, and in having the ovary 'inferior,' that is to say, sunk below the level of the perianth. In the daffodil and other narcissi the corolla bears a curious outgrowth which forms the **corona.** This family, like the *Liliaceae*, includes many bulbous plants, and is especially well represented in South Africa. In the semi-arid regions of that country the bulb rests below ground in dry weather, and springs into life with the onset of the rains. *Haemanthus*, *Amaryllis*, and *Nerine* are grown in our gardens and greenhouses for their brilliant flowers. The Agaves are American plants attaining the stature of small trees.

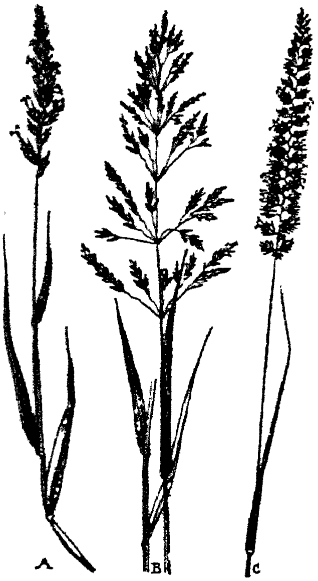


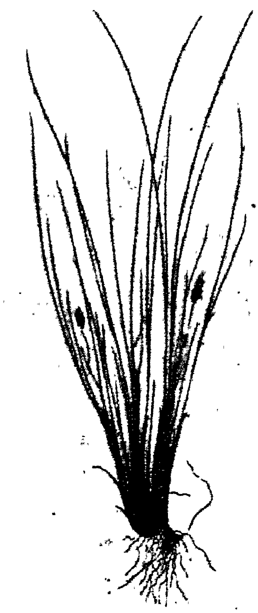
FIG. 383. COMMON GRASSES
A, sweet vernal-grass; B, meadow-grass; C, crested dog's tail.

Iridaceae. The iris, like the snowdrop, has an inferior ovary, but it possesses only three stamens. This easily distinguishes the flower of a *Crocus* from that of a *Colchicum*. *Iris* has a peculiar flower with three perianth segments standing erect and three folded back. On these lie three curious styles, each in form and colour like another petal. The stigmatic surface is on the underside of the style, protected by a little flap, and below it lies a stamen. A bee on visiting the flower can touch the stigma only as it pushes in, and not as it draws back, so that only pollen from another flower can be deposited on the stigma. Many other garden plants belong to this family: *Gladiolus*, *Montbretia*, *Ixia*, *Sparaxis*, and *Crocus*. We ought to grow more varieties of crocus than are to be seen in most gardens. There are most lovely autumn species which send up their flowers in a season of scarcity and produce their leaves in the following spring.

Gramineae. The grasses form the most important family of Monocotyledons, for not only are they the dominant plants of the meadows of temperate regions, but they include all the cereals—oats, wheat, barley, rye, maize, rice, millet, and others, which are the chief food of man and beast. The grass is usually a modest herb with a creeping

stem, throwing up leafy shoots as in the meadow-grass, or with tufted shoots as in the hair-grass. Tree-grasses occur in the tropics and are familiar as the bamboos. These throw up tall woody shoots which branch from year to year, periodically flower, and then die. The creeping habit of many of our native grasses is useful, for on it depends the formation of turf. The underground runners of the twitch or couch-grass make it a difficult weed to eradicate, for the plough or harrow breaks them up, and the fragments start new plants. The same habit in the marram-grass enables it to bind together the sand of the shifting dunes.

The grass leaf has a sheathing base which can be easily split away from the stem. The stem is markedly jointed and the joints have the peculiar property of renewing their growth if the stem is laid by wind or rain. The lower side grows more rapidly and brings the shoot upright. The grass flower is small and green. Several flowers usually grow together in an ear, enclosed between two scales or **glumes.** Each flower has three stamens, and an ovary with a single seed; these are enclosed by two thin scales or **pales.** When the flower is mature the pales are forced apart by the swelling of two little knobs at the base of the pale and the stamens, and feathery stigmas hang out. The light pollen is scattered by the wind, and its abundance is keenly felt by some unfortunate people, for the irritation it causes to the mucous membrane brings on **hay fever.** Though the grass flower is small it is grouped in most beautiful inflorescences, stiff and narrow as in the rye-grass, light and elegant as in the hair-grass, massive as in the cocksfoot-grass. The pampas-grass (*Gynerium*), with its tall and graceful panicles of white flowers, is an autumn ornament of many a garden.



Natural Hist. Museum

FIG. 384. COTTON-GRASS

Cyperaceae. The sedges are the grasses of marshy land, and indeed they are often confused with the grasses, for they have the same sort of leaf, but they can be distinguished by their angled stems and by the fact that the leaf-sheath is not split down the side. The inflorescences

are often of two different kinds borne on one shoot: drooping, soft clusters of male flowers and spiky tufts of female flowers. Many species of *Carex*, the sedge, occur in Britain. The cotton-grass (*Eriophorum*) is another familiar representative. The club-rushes (*Scirpus*) are common in moorland districts. To this genus belongs the true bulrush (*Scirpus lacustris*), though that name is sometimes given to the reed-mace, a plant belonging to another family. In East Anglia *Cladium mariscus* forms dense thickets in the fens, almost impenetrable because of the sword-like edges of its great leaves. It is used for thatching.

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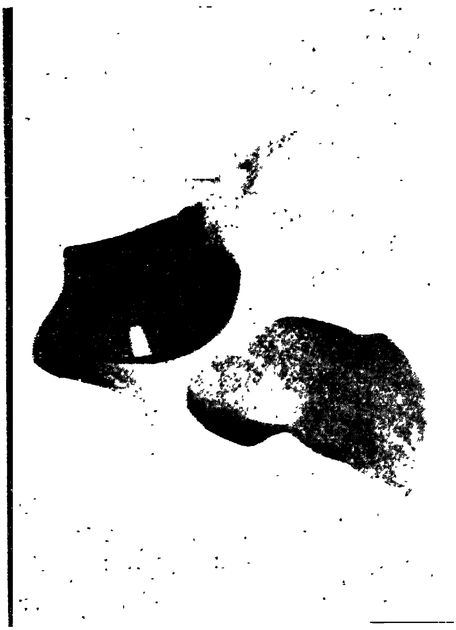
FIG. 385. PALMS

Palmeae. The only important family of monocotyledonous trees is that of the palms. They are trees of the tropics and sub-tropics, where they may form forests. Some are just hardy enough to be grown in gardens in the south of England, to corners of which they lend an exotic appearance. The tall stems with their crowns of quaint, feathered leaves remind one rather of tree-ferns than of flowering plants. The flowers, individually inconspicuous, are massed in very large inflorescences. The products of many species are of great practical importance.

Naiadaceae. This is an aquatic family, from the Greek *naias*, a fresh-water nymph. Some members are pondweeds, common in ditches, ponds, and slow streams. Some species lie entirely submerged but for their flowers, others have floating leaves. The broad blades rest on the water, unwettable because of their waxy cuticle, and rising and falling easily with the water-level because of the long slender stalks. The family includes, too, the grass-wracks, of which *Zostera*, so called from its ribbon-shaped leaves, is to be found on our shores, one of the rare salt-water flowering plants. *Zostera* and a related genus, *Posidonia*, are conspicuous in the Mediterranean, where storms may dump

them on the shore in heaps. They were used for the packing of Venetian glass, and even to stuff upholstery and to thatch roofs. These plants are almost unique in having their pollen transported by water.

Araceae. This great family is predominantly tropical, and in the rain forest it contributes one important element to the vegetation which lives on the trunks and branches of the trees. To us it is familiar in the wild cuckoo-pint or lords-and-ladies (*Arum maculatum*), and its close relatives the arum lilies. The hood of the native cuckoo-pint corresponds to the white expanded sheath of the arum lily: both shelter a thick spike-like inflorescence with small flowers of two kinds, male and female. The axis terminates in a curious club. The epiphytic species have special roots which hang down in the air, and are provided with a spongy outer layer capable of absorbing and storing rain and dew. *Monstera*, a climbing shrub, has edible fruits. *Colocasia* is the taro. The duckweeds (*Lemna*) are closely related to this family, and represent a stock which has become very much simplified by reduction from a former more complex state. The duckweed frond is really a flattened stem in which are sunk tiny inflorescences rarely seen; there are no leaves and a single root hangs down into the water. *Wolffia arrhiza*, the rootless duckweed, is a rounded green grain, without even a root. The duckweeds multiply by budding out new fronds, which break away and form independent plants. The rate of propagation by this means is very great, as we realize when we view the green of a duckweed-covered pond, so solid-looking that a dog will try to walk on to it.



Charles Jones

FIG. 386. ARUM LILIES

Orchidaceae. This is another great family which is predominantly tropical, though we have a fair representation of native species. The

pale purple-flowered spotted orchis (' spotted ' because of the purple-brown blotches on the leaves), the deep-red broad-leaved orchis, the lilac sweet-scented orchis, and the elegant white butterfly orchis, also scented, are quite familiar in spring meadows and marshes. On the chalk downs grow the bee and spider orchises, with their flowers resembling these insects. The lady's slipper is a great rarity, but related tropical *Cypripedia* are well known in greenhouses. Our native orchises all grow in the earth and many are tuberous-rooted. Many tropical forms are tree-dwellers, and their air roots are even better furnished with absorbing tissue than those of the arums. Some orchids have taken to the saprophytic mode of life and have lost their chlorophyll; native examples are the coral-root and the bird's-nest orchis.

Charles Jones

FIG. 387. LADY'S SLIPPER ORCHIS

The flower has a highly specialized structure which varies a great deal throughout the family. The corolla is attractive and highly coloured, and is often provided with a long spur in which visiting bees seek nectar. Usually there is none, and the insect must pierce the soft cells to suck the juices. There is only a single stamen united to the stigma. The pollen is glued together in two lumps or *pollinia* (p. 1150) set on little stalks. The base of each stalk has a sticky covering, and this sticks to the head of a visiting insect pushing against the stamen. A bee leaving an orchis flower may be seen bearing on its head the two club-shaped pollinia, which droop as it flies and are pushed against the stigma of the next flower visited. We may experiment with the working of this mechanism by pushing a pencil-point into the opening of the flower. There is great variety in the details of this floral mechanism, described in Darwin's great work, *The Fertilization of Orchids*. The lady's slipper, for instance, has quite a different floral structure and mode of pollination.

Dicotyledons

ARCHICHLAMYDEAE.

Salicaceae. We find that many of the great families of Dicotyledons stick to one type of growth-habit, and this is true of the *Salicaceae*, which includes the two genera *Salix*, the willows, and *Populus*, the poplars, all of which are trees and shrubs. Some of the willows

Fig. 388. Oak

which grow in Arctic and Alpine conditions are dwarfs. *Salix herbacea*, which may be found on our higher mountains, lies close to the ground, and, as its name indicates, is almost a herb. The willows are characteristic of damp marshy woods and stream-side vegetation, and are specially abundant in the temperate regions of Europe and America. Both willows and poplars bear their flowers in **catkins** (see Fig. 373), that is, inflorescences that fall off as a whole. The sexes are separate and are borne on separate plants. The poplars are pollinated by wind, but the willows produce nectar and are visited by the early bee. Though the individual flowers are small and have no petals, the effect of the whole inflorescence—especially of the male, covered with yellow stamens—is bright. The inflorescence is the more conspicuous for being produced before the leaves. Many American poplars are grown in this country, noteworthy examples being the

sweet-scented *Populus trichocarpa* and *Populus canadensis*, the balsam poplar. They are useful because of their extraordinarily rapid growth. The Lombardy poplar owes its striking form to the very erect habit of its branches.

Fagaceae. This is another family of trees, which includes the beeches (*Fagus*), the oaks (*Quercus*), the sweet-chestnuts (*Castanea*), and some others. These are of great importance as forest-formers in northern temperate regions. The flowers are small and inconspicuous, the male and female borne in small catkins on the same tree, and appearing before the leaves are fully expanded. Pollination is by wind. There are numerous species of oak, two closely similar, the common oak and the durmast oak being native in Britain. They are rugged, noble trees, especially when grown in the open so that their branches have full freedom to spread; and they attain a great age. The holm oak or Ilex is an evergreen of the Mediterranean region, where its hard and leathery leaves well withstand the drought of summer. It is much planted in this country. The cork oak and the Turkey oak are also evergreens. Some of the American species colour brilliantly in autumn. In Patagonia and New Zealand, forests are formed by evergreen beeches. A closely related family, the **Betulaceae,** includes the alders, birches, hornbeams, and hazel.

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FIG. 389. CARNATIONS

Caryophyllaceae. The Carnation family is one of herbs. The form of the flower is well shown by the stitchwort with its five starry, white petals, ten stamens and five carpels joined together, with but a single cavity containing numerous ovules on a central stalk. The stitchworts have other bright and common hedgerow relations in the campions, catchflies, and chickweeds. Rarer are the pinks, such as the beautiful maiden pink and the Cheddar pink. From these have been developed our garden carnations. To the same alliance belongs the Goosefoot family, **Chenopodiaceae,** which includes many rank weeds, the goosefoots, the beets, and a number of fleshy-leaved shore plants, the oraches.

Polygonaceae. These are plants of waste land. The docks are

despised as weeds, though they are often handsome enough. The sheep's sorrel, a small species most abundant on poor, sour land, has brilliant, ruddy flowers, as has the sorrel, another small species the leaves of which have a pleasant acid taste—and serve as a salad for country children. We may refer in passing to the virtues of the rhubarb, different species of which yield material for tarts and physic.

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FIG. 390. MAGNOLIA IN SPRING

Ranunculaceae. One of the most interesting groups of plants is that of which the Buttercup family is a member. In its circle are also the **Nymphæaceae** (the Water-lily family), **Magnoliaceae** (Tulip-tree family), **Calycanthaceae** (Allspice and Winter-sweet family), and **Lauraceae** (Bay Laurel family). Their interest lies in this, that they all possess, what it is agreed to regard as a primitive type of flower. As in the buttercup the parts are usually separate; there is a tendency to arrangement in spirals instead of the more usual whorls; the ovaries are superior. Frequently there is a transition from one part to the other, as in the water-lilies, where the stamens, as we follow them outwards, gradually change their form and assume the shape of petals. The stamens and carpels and even the petals may be numerous. It is thought that such a flower represents an earlier stage in evolution than that, for example, of a primrose, where the parts are few in

number and always in fives, and where the petals and sepals are united. The flowering plants, it is thought, have evolved from a laxity of numbers and arrangement, and freedom of parts, to a condition of greater definiteness. It is certain, too, that at least some of these families are very ancient. The magnolias and laurels are numerous among the early Cretaceous fossils of flowering plants. The distribution of the Magnolia family confirms the opinion: different species are native in Japan and eastern North America, but nowhere in between. Such a discontinuous distribution may often be taken to indicate an ancient group, which once occupied an extended area but has largely died out, leaving only scattered relics. A curious fact is that some water-lilies and related plants are pollinated by beetles. This is very unusual. Beetles are among the most ancient of insects, and it is possible that the association may have been formed in a much earlier geological epoch and have persisted till to-day.

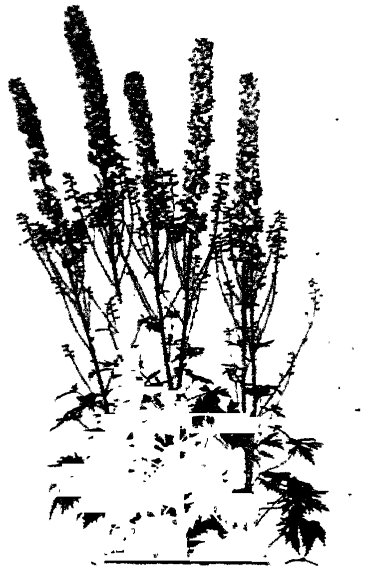

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FIG. 391. LARKSPURS

Many people would perhaps imagine that a small flower, of the oak or willow type, with no perianth and a very simple structure, would be more likely to be primitive. But for many reasons it is easier to imagine the flower to have started as a large and complicated structure and to have evolved simpler types by reduction—that is by losing, say, its perianth—than to imagine a flower without a perianth evolving one. A calyx we can be fairly sure is equivalent to a whorl of leaves, but if you have a simple flower without any leaves in its neighbourhood—like that of a willow—where, in the course of evolution, is a perianth to come from? The question as to whether simplicity is primitive or derived is one which is continually cropping up in connection with the evolution of plants. Of course there is no direct method of answering it. Indirect arguments often fail to produce agreement. Botanists are still not agreed as to whether flowers of the buttercup type or those of the oak type started the evolution of the flowering plants. It is

quite possible that both views are correct, and that the flowering plants, though they have many features in common, really include two, or even more, independent stocks—just as we are sure the gymnosperms do. After all, oaks, as well as magnolias, grew in early Cretaceous times.

The *Ranunculaceae* is a varied family. The genus *Ranunculus* itself, the buttercup or crowfoot, is large, and grows in the most diverse situations—meadows, alpine bogs, woods, and in water. Water-crowfoot may have only submerged or also floating leaves; it stars the surface of our ponds with white flowers. The genus is found all over the world. Anemones, pheasant's-eye, peonies, winter aconite, Christmas rose, larkspur, columbine, monkshood, are all familiar members of the family and indicate how varied in form are the flowers. Yet fundamentally a columbine is just a buttercup with spurred petals turned red or blue. *Thalictrum*, the meadow rue, is an interesting genus with wind-pollinated flowers. *Clematis* alone is woody and a climber; the feathery stigmas of the old-man's-beard decorate our hedges in autumn, and the more gaudy flowers of many foreign species are common in gardens.

Charles Jones

FIG. 392. WALLFLOWERS

Cruciferae. This great family includes herbaceous plants easily recognized by the structure of the flower. Four separate sepals enclose four separate petals, their limbs standing out as the arms of a cross. The six stamens are arranged four in pairs and two single: two carpels are united in one ovary. This ripens into the pod, perhaps most familiar in shepherd's-purse and honesty. When it splits into two valves it leaves a central membrane on which the seeds hang (the silvery pennon of the dried honesty), till jerked off by a passing animal or by the wind. Turnip, cress, mustard, cabbage, radish, and many others are used as vegetables and point the fact that a physiological quality like edibility may run in the family. Shepherd's-purse, treacle

mustard, wart-cress, and others are weeds, while the stocks, wallflowers, and candytuft are favourite garden flowers.

The Rose family or **Rosaceae** is a good example of one with very varied growth-habit, for it includes herbs, such as the strawberry, tormentil, and avens; shrubs like the brambles and roses; and small trees, as the apple, pear, plum, and cherry. A prominent character, evident from this list, is a tendency to bear fleshy fruits. These are very varied in nature. The strawberry is really the fleshy axis of the flower, with little carpels growing all over it: the rose hip is again a fleshy axis which has grown up to form a flask in which the carpels are enclosed. In the cherry, on the other hand, the outer layers of the fruit-wall are fleshy and the inner a stone. The core of the apple is the real fruit, and the flesh is the flower axis grown around and completely fused with it. There is, then, a tendency in the family for the axis of the flower to grow up round the carpels, or rather for the carpels to sink in the flower axis. This may very well mean better protection and more efficient nourishment. This tendency with some other features marks the floral structure off from that of the buttercups, to which it is often superficially similar. The *Rosaceae* do not only provide us with a variety of common and refreshing fruits, for the family includes the 'cherry hung with snow' and its relations, among the most beautiful of flowering shrubs, but it may render a garden gay with geums, potentillas, and spiraeas, as well as with that most varied genus *Rosa*, the rose.

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FIG. 393. ROSE WITH HIPS

Saxifragaceae, a family which includes the currants, gooseberries, and exotic shrubs such as the *Escallonia*, as well as the saxifrages; and

the **Crassulaceae,** including the stonecrops (fascinating to the rock-gardener) are related to the *Rosaceae*, as is also one of the most important, as well as the largest, of families of flowering plants, viz. the **Leguminosae** or Pea family. The fundamental reason of its importance to man is that the seed stores unusual amounts of protein reserves. Peas, beans, and lentils are richer in protein than any other vegetable food, and so are very valuable when meat is scarce. It is usually from the bean or lentil that the vegetarian cooks his humble 'cutlet.' This second-largest family of flowering plants—it includes nearly ten thousand species—is characterized most readily by its fruit, the pod, or **legume,** derived from a single carpel which splits into two valves when ripe. The butterfly type of flower familiar in sweet-pea, gorse, and scarlet runner has an erect petal behind—the **standard,** two **wing** petals, and two front petals joined round the stamens and stigma in a **keel.** The flowers, with deeply hidden nectar, are visited by long-tongued bees, and the mode of bursting open of the keel habitually assures cross-pollination. The *Leguminosae* occur as herbs—clover, lupine; climbers—vetches, peas, *Wistaria*; shrubs—gorse, broom, rest-harrow; and trees—false acacia. The Judas tree is remarkable in bearing its pink flowers in short shoots springing from the trunk. This family includes a sub-order of exotic plants in which the butterfly form of flower is departed from though the characteristic fruit is retained. Examples are the 'mimosas' of the flower-shops belonging to the genus *Acacia*. In addition to the various species valuable to the florist, this genus includes the Australian 'wattles,' important as forest trees.

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FIG. 394. MOSSY SAXIFRAGE

The gorse is a shrub which makes remarkable growth in the dry and barren soils of our heaths. Its success is due partly to its resistant needle-leaves and spiny shoots, and partly to the formation of root-tubercles, in which are symbiotic bacilli which fix the nitrogen of the

air and make available a supply of the scarce and essential compounds of this gas. The faculty is shared by the other members of the family, and their growth is important in increasing soil fertility. In the semi-arid regions of steppe and prairie leguminous plants form an important feature in the vegetation, as they do also in the still drier semi-deserts of America, Africa, and Asia.

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FIG. 395. BITING STONECROP

Geraniaceae. This small family is represented in Britain by the crane's-bills (*Geranium*) and the stork's-bills (*Erodium*). The meadow crane's-bill is a gay purple flower in our hedgerows, and the pink flower and reddish stems of herb Robert shine in shady places. The cultivated 'geranium' belongs to the related genus *Pelargonium*, important in South Africa. The family is botanically interesting from the way in which the fruits are spread. Each of the five carpels splits off, enclosing a seed, and hangs by a long spike or awn which screws or winds up as it dries. The straightening and curling of this awn with changes in moisture pushes the carpel along the ground, and may push it into soil crevices and help to bury it. The family is characterized by a tendency to bear glands secreting an aromatic oil. The oil of *Pelargonium odoratissimum* of Algeria is used in perfumery. Related families include *Tropaeolum* (**Tropaeolaceae**) and *Oxalis* (**Oxalidaceae**), familiar as garden plants, and the flax (**Linaceae**), from which fibres and oil are obtained.

Rutaceae. This large family is mainly tropical, but the rue (*Ruta*), dittany (*Dictamnus*), and *Choisya* are often cultivated. All exhibit an important characteristic, the formation of glands producing aromatic oil. So abundant are these in the dittany or 'candle-bush' that, on a calm day, a match applied to the plant lights a flame which flares over it for a second. The most important members are the sub-tropical shrubs and trees of the genus *Citrus*, which includes the lemon, orange, lime, and grape-fruit, in all of which the production of aromatic oil is so pleasant a feature.

Euphorbiaceae. In the British flora we have about a dozen species of *Euphorbia*, the spurge, on the seashore, in the woods, and as garden weeds. When broken across, the stem exudes a white juice. The similar juice of a tropical tree, *Hevea brasiliensis*, yields the world's main supply of rubber. The flowers are most peculiar. A number of male flowers, each consisting of a single stamen, surround a female flower consisting of three united carpels. The whole is sheathed by a number of small, united bract-leaves, and the whole little inflorescence resembles a flower. In our species it is usually rather inconspicuous, though in some it looks like a bright yellow-green flower. In some exotic species the sheath is brilliant scarlet. One, in which inflorescence is associated with a bright scarlet leaf, is the *Poinsettia* of our greenhouses. Euphorbias are especially numerous in South Africa, where they are important desert plants. Many desert species have fleshy stems and lack leaves. They are often surprisingly like cacti, from which they can be readily distinguished by the possession of milky juice. The dog's-mercury is another British representative of this family, which is, however, predominantly tropical. *Ricinus* (the castor-oil plant), *Manihot* (the cassava, which yields tapioca), and *Croton* are important representatives.

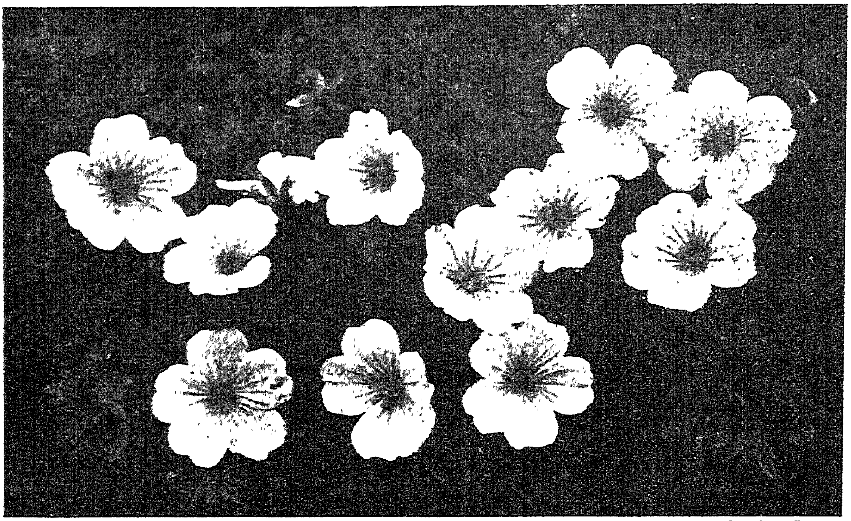
Charles Jones

FIG. 396. LABURNUM

Aceraceae. We mention this as an example of a family of trees. The hedge maple is the only one native in Britain, but the sycamore maple and the Norway maple have been so widely planted, and regenerate so freely, that they are established as denizens of our country-side. They are examples, as is the lime, of insect-pollinated trees—an uncommon feature in temperate lands. The flowers are not conspicuous but are produced in great numbers, and, as they are particularly rich in nectar, they are eagerly visited by bees. Many North American maples have brilliant autumn foliage and contribute

to the rich colours of the woods in the fall. The horse-chestnut belongs to a related family.

Cactaceae. This family has about a thousand species native in the dry regions of tropical and sub-tropical America. Its members are familiar to us in hothouses and some are almost hardy in this country.



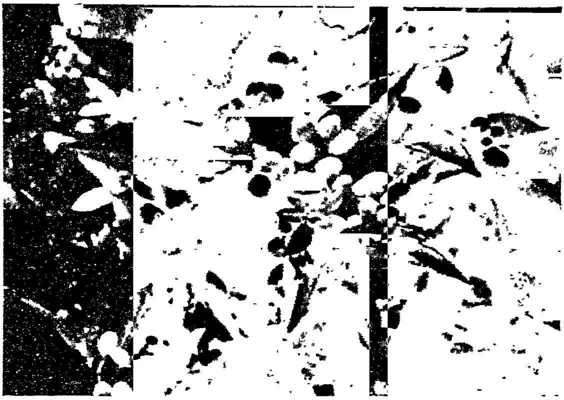
Charles Jones

FIG. 397. MEADOW CRANE'S-BILL

Scarcely any are native in the Old World, but they have been introduced to South Africa and to Australia, and, in the latter continent, the prickly pear (*Opuntia*) is now a pestilential weed. They are typically desert plants, with great swollen water-storing stems often jointed, and protected from browsing animals by formidable thorns. Some, like the giant *Carnegiea* of Texas, reach a height of forty feet. The flowers are large in size and brilliant in colouring. The power of existing in very arid conditions is due to two things: their wide-spread surface roots, which enable them to absorb with great efficiency water that falls in the desert from the slightest shower; and their capacity for living for months and even years on the water stored in their fleshy stems. A cactus may lose more than half its weight in a prolonged drought and yet survive.

Umbelliferae. This is one of the most easily recognized of families, for nearly all its members have small flowers, usually white, grouped in large flat heads or **umbels.** Here the smallness of the individual

flower is compensated for by the orderly arrangement of the inflorescence to give a showy effect. The flowers at the margin of the inflorescence frequently have larger petals to the outside, thus further increasing showiness. The leaves are usually large and much divided, as those of the hemlock. The ribbed hollow stems, productive of aromatic oils in internal glands, are also characteristic. Cow-parsnip, hemlock, chervil, earthnut, alexanders are wild in England. Celery,



Will F. Taylor

FIG. 398. ORANGE BLOSSOM

parsley, fennel, carrot, and others owe their culinary value largely to an aromatic flavour. Many members contain poisonous alkaloids. The hemlock is well known and the water-hemlock, or cowbane, sometimes causes poisoning of stock. The giant cow-parsnip, sometimes seen in shrubberies, is an instance of the size to which a herbaceous perennial may attain. The sea-hollies show a curiously modified type of the inflorescence, and in their hard spiny leaves have an adaptation to life on a wind-swept shore.

METACHLAMYDEAE.

Primulaceae. The primrose flower is a good type of the second great class of Dicotyledons. Both sepals and petals are united. The corolla shows us how a deep tube, probed only by a long-tongued insect, and formed from the united parts of the petals, may be combined with a flat expansion at once showy and offering a platform to the visiting bee. The five stamens are set inside the corolla tube, a common feature of flowers with united petals. The carpels are united and form an ovary with a single cavity containing many seeds set on a basal knob.

British primroses, *Primula acaulis,* grow best in sheltered places, with soft, sappy soil, away from frost and storm, dust and drought, and we suppose that is what people mean by 'the primrose path.' It does not seem to be crowded in these strenuous times!

In Wild Nature, however, we know it well, leading along the soft slope of a well-watered wood, whose shade is often broken by sunlight, where the soil is rich with vegetable mould, and insects come and go. The bank above us and below us is starred with primroses, and as we loiter along the primrose path we come to glades which are almost carpeted with pale gold. Every one likes the primrose because, as its name suggests, it has priority in spring; because it blossoms so generously—sometimes a score of flowers from one rosette; and because of its delicate beauty and fragrance.

FIG. 399. COLLECTING RUBBER

It is plain that the primrose must waken early, for it has almost no above-ground stem, and it must get a start before it is hidden by the taller vegetation of the wood.

From the apex of a short, erect root-stock (really an underground stem) there develops a rosette of strong leaves, which have time to make large quantities of starch and the like before the taller plants of the wood have well begun. The reserves pass down into the short stem and its branches (which may start new plants), and thus the primrose has abundant savings laid up for rapid expenditure in flowers the following spring.

As the primrose is perennial, the short stem would be bound to rise in the course of years if it were not for the somewhat unusual activity of 'contractile roots,' which shorten by altering their structure, and positively pull the little vertical stem down into the ground.

As in the primrose's first cousin, the cowslip or *Primula veris*, there are two kinds of flowers, as one can see at a glance. About half of them are 'pin-eyed,' with the stigma of the pistil occupying the mouth of the corolla tube, while the five stamens are half-way down. The other half of the primrose plants are 'thrum-eyed,' with the stamens at the mouth of the corolla tube, and the short-styled stigma about half-way down the throat. The pollen grains of the thrum-eyed flowers are rather larger grains than those produced by the stamens of the pin-eyed flowers.

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FIG. 400. SYCAMORE MAPLE

Careful observation has shown that the pollen-carrying insects, such as bees and small moths, transfer pollen from the low-level stamens of one plant to the low-level stigmas of another, and from the high-level stamens of one plant to the high-level stigmas of another; and it may be noted that the larger pollen grains of the thrum-eyed flowers are suited to the somewhat coarser stigmatic surface of the pin-eyed flowers.

Charles Darwin showed with his wonted patience that what he called the 'legitimate' pollination of thrum-eyed stigma by pin-eyed pollen usually produces more seed and more vigorous offspring than 'illegitimate' pollination, such as thrum-eyed stigma by thrum-eyed pollen, or pin-eyed stigma by pin-eyed pollen. As 'legitimate' pollination is what occurs in Nature, a continual crossing of the two different races is kept up, and this, as Darwin proved, is best for the species.

Since Darwin's day the researches of Bateson and Gregory have shown that the difference between thrum-eyed and pin-eyed is due to a 'Mendelian hereditary factor' (cf. p. 987).

Long-styled or pin-eyed plants are 'homozygous recessives,' while short-styled or thrum-eyed wild primroses are all 'heterozygous dominants.' So that we must not say of the Mendelian what Wordsworth said of another, that

A primrose by the river's brim,
A yellow primrose was to him,
And it was nothing more.

On the contrary, to the Mendelian the primrose plant is either a 'homozygous recessive' or a 'heterozygous dominant.'

The most important fact is that high-level pollen is landed by insects on high-level stigmas, and low-level pollen on low-level stigmas, and these are the only crossings that yield the full complement of fertile seed. Darwin once said that 'bees are good botanists,' for they seem to distinguish the different species of flowers so accurately; but, thinking of *Primula* and the like, he might also have said that they were good geneticists.

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FIG. 401. CACTI

If primroses are hooded so as to keep insects out, no seeds are formed. If the blossoms are hooded by day but exposed at night, almost no seeds are formed, which shows that nocturnal visitors—and there *are* some—hardly count for pollination. There is no doubt that the pollination is effected by day-flying insects, such as bees, butterflies, and diurnal moths.

There are numerous species of Primula, mostly in the northern hemisphere, and chiefly in hilly districts. The majority are so beautiful that we cannot wonder at the enthusiasm of primrose devotees.

'An Alpine slope illumined by the purple glow of *Primula glutinosa* in its full glory is a spectacle of such surpassing beauty

that he who has once beheld it carries within his bosom for ever a glad recollection and an unappeasable longing.'

But the same might be said of scores of different kinds. Thus, who can forget the shy and hardly cultivable *Primula scotica* with its rich violet-purple corolla intensified by a yellow throat? Primulas from the Alps and primulas from the Himalayas, primulas Indian and primulas Chinese — what a winsome company! Not only are there over two hundred different kinds, each itself and no other, but there are cultivated varieties in embarrassing numbers and hybrids unending, even in Nature.

FIG. 402. HEMLOCK

The only warning to devotion that we can think of is: not to caress *Primula obconica*, so common in greenhouses, for its glandular hairs secrete an inflammatory juice.

Charles Jones

FIG. 403. PRIMROSES

Ericaceae. This is an example of a specialized family. The heaths are most abundant in South Africa and Mediterranean countries. In Britain we have only half a dozen species, but the ling is so widespread on moors that it is an important element in our flora. The dwarf shrubby habit and the small leathery leaves make the plant highly drought-resisting. The tall Mediterranean heath is at home on the arid *garigues* of South France and Algiers. The ling occupies most successfully the thin dry soil of the heather moors, though it and other heaths live also on wet, deep peat. The bell-shaped flowers

are eagerly visited by bees, and yield a famous honey. Heaths

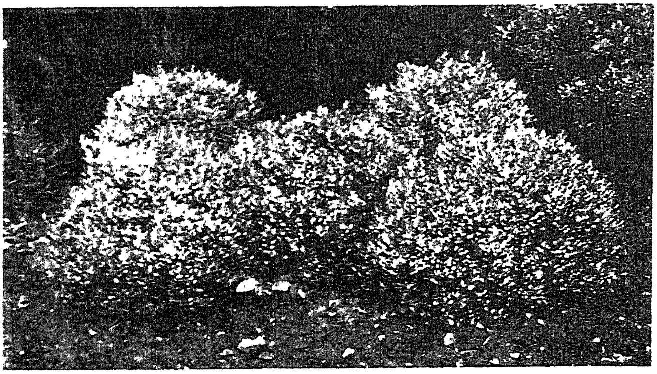

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FIG. 404. LING

are valuable as denizens of rock-gardens and as pot plants. The growing of several of the brilliant African species for the Christmas market is a highly specialized branch of the gardening industry.

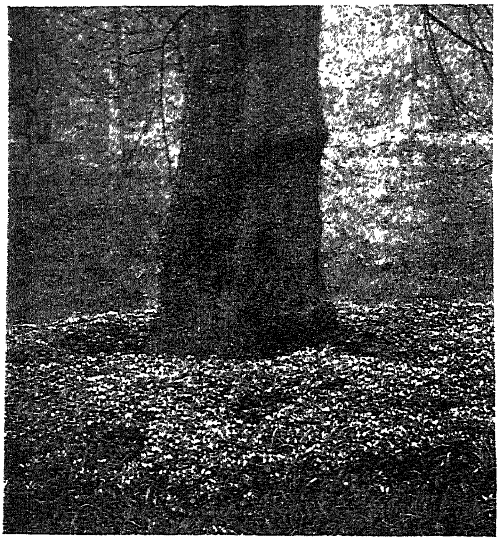

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FIG. 405. WHITE DEAD-NETTLES

Labiatae. Plants of this family can usually be easily recognized by the form of the flower. The corolla is divided into two lips: under the hood of the upper the stamens and stigma are sheltered, while the lower expands into a broad landing-stage for insects. Excellent examples are the sage and the white dead-nettle. When a bee visits the flower it enters so that its back touches either the stamens or the stigma, which come in its way at different periods of the flower's life: in this way cross-pollination is effected. It should be noted that the visit of the bee can take place only in one way—it must land on the platform

and push under the hood. This is brought about by the fact that the flower is bilaterally constructed and not radially like the primrose. The development of this bilateral type of symmetry is to be regarded as an advance in construction. It is characteristic of some whole families. In others it has been evolved by some of the genera only. For example, the monkshood and larkspur have bilateral flowers, though radial symmetry is the rule in the *Ranunculaceae*. The *Labiatae* include many herbs and small shrubs. Mint, thyme, rosemary, marjoram, sage, lavender, deadnettle, woundwort, ground ivy, catmint, and bugle are all well known. These names will remind us that the production of aromatic oils is a frequent feature. The family is well represented in the flora of dry steppes and prairies. It is the abundance of lavender and rosemary which scents the air in hot weather in southern France and Corsica. Several exotic sages, e.g. *Salvia splendens*, with brilliant scarlet and crimson flowers, are grown in gardens and greenhouses. These are interesting as examples of flowers pollinated in their native lands by small birds instead of insects.

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FIG. 406. SNAPDRAGONS

Scrophulariaceae. The foxglove, the snapdragon, and the speedwell are good examples of different floral types in this family. The bilateral symmetry we have noted in the *Labiatae* is marked here, and sometimes carried to greater lengths. The mouth of the snapdragon corolla is so pursed up that it opens only to the weight of a heavy bee. The toadflaxes have the corolla produced back into a long spur. Eyebright, cow-wheat, and red rattle are common wild plants which have taken to partial parasitism, their roots uniting with, and drawing on the supplies of the roots of the plants among which they grow. They are not obviously parasitic, for they have green leaves and can assimilate

carbon dioxide. Yet the cow-wheat cannot grow without its host. In *Lathraea*, the toothwort, and the broomrapes (*Orobanche*) the tendency to parasitism has taken full effect, and these form only scale-leaves with no green pigment. *Orobanche hederae* may be found frequently sending its brownish shoots up from the beds of ivy on the roots of which it grows. The toothwort may be noticed about the roots of hazels, ashes, and other trees.

Natural History Museum

FIG. 407. COFFEE TREE

Many valuable garden flowers belong to this family. New Zealand has sent us many species of the shrubby *Veronica* or speedwell, which are peculiar to that island. Some of them show a curious resemblance in their shoots to other plants, for example the cypresses. Mulleins and pentstemons are also familiar.

Rubiaceae. This family is represented in this country by a number of species of *Galium*, the bedstraw, of which the yellow lady's-bedstraw

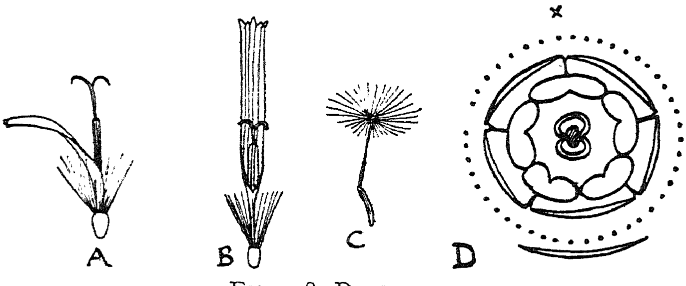

FIG. 408. DANDELION

A, single floret, side view; B, single floret, front view; C, fruit with pappus; D, plan of floret.

is the most beautiful; by the woodruff of beech woods, and its dainty relation the squinancywort of the chalk downs. *Rubia*, the madder, the red dye of which was formerly so important, is also a native. But the family is one which is predominantly tropical. Our small herbs

with their characteristically whorled leaves give a poor idea of its variety. The *Gardenia* is a greenhouse plant which gives an intimation of another habit of growth. Many shrubs and trees of the tropical forests are members of the family, and we may mention *Coffea*, the coffee, and *Cinchona*, the bark of which yields quinine, as examples of economic importance.

Compositae. This is the largest family of flowering plants, probably comprising one-tenth of the whole group. It occurs over nearly the whole surface of the earth, and in it the flowering plant has probably reached the present summit of its evolution. It carries further the plan seen in the *Umbelliferae*, the plan of massing a number of small flowers in a showy inflorescence. The 'flower' of the daisy, dandelion, and chrysanthemum is really an inflorescence. In the daisy the head bears two kinds of flowers, those in the centre tube-shaped with both stamens and ovary, and those at the edge strap-shaped, without stamens or completely sterile. In the thistles all the flowers are tubular; in the dandelion all are strap-shaped. A general rule is the expansion of the edge flowers, producing greater display. The stamens form a tube out of which the growth of the stigmas pushes a little heap of pollen. After this has been brushed away by a visiting insect the two stigmas unfold, and may be pollinated from another head. But if this fails they curl back and touch the pollen scattered about amongst the flowers. The 'seed' of a dandelion or thistle is really a little fruit containing a single seed. In most members of this family it is crowned by a tuft of light hairs, the **pappus.** As any one may see on an autumn day in a field of thistles, these downy fruits are well suited to travel by air. The lightest breeze may keep them floating for miles. This admirable arrangement for fruit-dispersal is undoubtedly one of the

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FIG. 409. DAHLIAS

chief factors which have covered the wide world with Composites. *Olearia*, the daisy bush, is a shrub, and in the mountains of Central Africa some strange species of groundsel attain the height of small trees (a canary's paradise?). But most of the family are herbs. Daisy, dandelion, groundsel, and thistle are only too familiar weeds, and the way in which they spread and replace other plants is an indication of the vigour which makes this a dominant family. In the sunflowers, chrysanthemums, *Cosmos*, *Dahlia*, asters, and marigolds we have examples of more desirable garden plants. Artichokes (globe and Jerusalem) lettuce and salsify are useful vegetables.

CHAPTER XIII

THE BUILD OF THE FLOWERING PLANT

Internal structure—The leaf—The stem—The root—Architecture.

Internal Structure

In our survey of the plant kingdom we saw how in the algae and fungi various plans of building construction had been tried out, and how one of them had proved in practice so superior to the others that on it all the plants of the higher groups had been built up. This was the *cellular plan*, in which the body is composed of a myriad of small units, as a house is of bricks: only each unit is, initially at least, alive, and the units are not mortared but grown together. The success of that plan is due to many things, but more than anything else to the way in which the cell-unit may vary. It appears in a multitude of forms, under which it can perform many different functions. When we reached the mosses and ferns we indicated only briefly this aspect of our subject, because in land plants it may best be dealt with for the flowering plants, in which the greatest complexity is found.

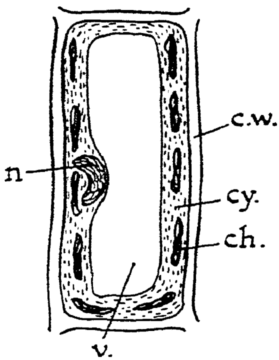

Fig. 410. Diagram of Cell from Leaf

cw, cell-wall; *cy*, cytoplasm; *ch*, chloroplast; *v*, vacuole; *n*, nucleus.

The cell was first discovered by the English microscopist Hooke in the seventeenth century, and the first cells he described were those of a piece of bottle cork, which is the bark of the cork oak. These cells are of course dead, and the empty walls which build up the substance of the cork were the important thing to Hooke. Later it was realized that plants and animals alike were composed of such units, and that the most important part of them is the living contents. If we may use the term we may say that the 'normal' plant-cell consists of a wall of cellulose, a lining of protoplasm, a central vacuole, usually very large, containing a watery sap, and, embedded in the protoplasm, the nucleus, the chloroplasts, and often other more obscure inclusions.

We say 'normal' because the presence of a cellulose wall and of chloroplasts is peculiarly characteristic of plant life. Let us see how the various parts of the plant are built up of such units.

The Leaf

The leaves of flowering plants are covered on both surfaces by a delicate skin, patches of which may often be peeled off. The experiment may be tried successfully with a tulip: an onion scale, which is just a kind of leaf, is even easier to flay. The skin is extremely fine and almost transparent; it consists of a single continuous layer of cells which in their proportions are not unlike a 'flat fifty' cigarette box. The cells of this **epidermis** contain no chloroplasts. Often the margins of the cells are not straight but wavy, and the different cells fit together like the pieces of a jigsaw puzzle. The whole epidermis is covered, as we have already said, with a **cuticle** of waxy substance. This is quite imperceptible to the naked eye, except when it is specially thick as in many evergreen leaves, such as the holly or cherry laurel. The polish of these is almost exactly the same as the waxed polish of a table-top, or a pair of boots. Sometimes in addition to the cuticle there is a coating of loose grains of wax, and this lends a **bloom** equally to a plum fruit and to a cabbage leaf.

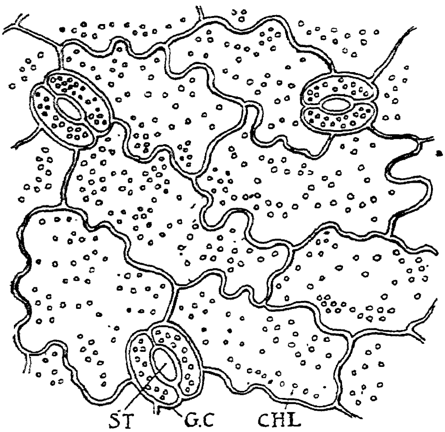

FIG. 411. EPIDERMIS OF LEAF
CHL, epidermis-cells; GC, guard-cells; ST, stomatal pore.

Epidermis and cuticle protect the leaf from too great loss of water-vapour. But we must remember that the first function of a leaf is to absorb carbon dioxide from the air, and cuticle is more impervious to this gas than to water-vapour. Carbon dioxide is admitted by large numbers of minute pores in the epidermis called **stomata**. Each stoma is surrounded by two special cells of the epidermis, shaped rather like sausages and containing, unlike the other cells of the epidermis, chloroplasts. The appearance of a stoma may be quite well visualized by thinking of two sausages lying alongside each other, joined by their ends and pulled slightly apart to leave a gap—the pore. The stoma may be about one-two-thousandth of an inch long and one-five-

thousandth of an inch broad, and is far smaller than the prick of the finest needle. Stomata are present in enormous numbers. The leaf of a sunflower has about 200,000 per square inch of surface: the epidermis of a moderately large leaf of a normal plant is pierced by millions. Even this great number possesses a combined area only a fraction of that of the whole leaf, yet they are surprisingly efficient. According to the laws which govern the passage of gases through very minute holes, the cuticle pierced by stomata absorbs carbon dioxide, and allows water-vapour to escape, about as well as if no epidermis and cuticle were present. How much better off then is the leaf, as regards prevention of excessive loss of water, than it would be if entirely deprived of its cuticle? The answer is that the stomata allow for a far-reaching control. In the first place, many leaves, for example those of beech, ivy, and ash, have stomata only on their lower surface. Now the upper surface is the one exposed to the sun, and, if its cuticle is unpierced by pores, the danger of over-drying is much diminished. This principle of control or protection by distribution is carried further in other plants where the stomata are sunk in pits or grooves, e.g. many grasses, and so further removed from the influence of dry air, wind, and sun. In the ling the edges of the little leaf are curled in backwards, folding over and protecting the stomata. In drought the leaves of the marram-grass roll in, completely enclosing the stomata.

In the second place, the stoma is itself capable of opening and closing. This comes about by changes in internal pressure of the guard-cells acting in a complex fashion, and bound up with the presence of the chlorophyll. The stomata do not always close when the air is dry, but in periods of drought they tend to close in the heat of the day and so limit the amount of water given off by a leaf. Plants with leathery leaves and thick cuticles whose stomata are closed in drought lose a minimum of water. Such plants as lettuce, sunflower, and *Tropaeolum* cannot so well withstand drought as a heath or holm oak, because their thinner cuticles allow appreciable amounts of water to escape even when the stomata are closed.

The only feature in the structure of the leaf obvious to the eye is the **venation.** It is clear from the way we can strip the midrib from a leaf that it is a fibrous structure: this is confirmed by examination of one of the skeleton leaves we may often pick up in a damp wood. The skeleton is just the fibrous framework of the veins. The function of the veins is threefold: they form a mechanical framework for softer tissues; they are the aqueducts of the leaf; they carry away the food substances formed in the leaf. Their detailed structure is the same as that of the conducting and strengthening tissues of the stem, and we shall leave its description till we deal with stems. We should note that they do not carry a *circulating* stream of fluid like the veins

of an animal. The word *nerve* which is also used to describe the veins is unfortunate, for they have no nervous function.

The space between the veins is filled with a softer tissue, in which cells of two kinds occur. Below the upper epidermis there may be one or two layers of cells each having the shape of a round cigarette tin. The flat ends are attached to the epidermis. They press against each other, with the sides flattening each other somewhat, but leaving crevices between. They are called **palisade-cells,** for a row of them looks very like a lath fence. Each palisade-cell is a 'normal' plant-cell with cellulose wall, protoplasm, nucleus, chloroplasts, and a watery vacuole. The chloroplasts are small biscuit-shaped objects, many in each cell and arranged round the side walls. The palisade-cells are the chief assimilating cells of the leaf. Below them a tissue graphically described as 'spongy' fills the space to the lower epiderm. Its cells are irregular in form, they fit loosely together and leave many spaces filled with air between them. They, too, contain chloroplasts, but fewer than the palisade-cells. Through the air-spaces in the spongy tissue carbon dioxide diffuses from the stomata to the walls of the palisade-cells, where it dissolves in moisture and passes to the chloroplasts. It is a great advantage to have spaces through which the gas can pass, for when dissolved in water it travels much more slowly. We can get some idea of the size of a cell by considering that an ordinary leaf may consist of about eight or nine cell-layers.

One other feature often shown by leaves may be referred to—the presence of **hairs.** At its simplest a hair is just an epidermal cell which has grown out into a long point. Often hairs are forked or branched and frequently they consist of a row of several cells. These cells may be dead and empty. Living hairs are often glandular, excreting various substances such as the aromatic oils of the *Pelargonium* (p. 1178). The hairs of the stinging-nettle have a bulbous base containing the poisonous fluid, and a hard point which breaks off at a touch, leaving a hollow hypodermic needle to penetrate the skin and inject the poison.

The Stem

If we cut across a young twig of a maple or other tree we can recognize the presence of at least four different tissues. To the centre there is a soft white stuff, the **pith,** surrounded by the hard, fibrous, pale yellow **wood.** Then comes the **rind,** greenish in colour, with a greenish brown **epidermis** to the outside.

The pith is of little importance: its cells die early and, as the tree grows, may disappear almost entirely. The wood is the main supporting and water-conducting tissue of the plant. In flowering plants it

is complex in structure. It consists in the main of long cells arranged with the length of the stem, and it is this regular arrangement which gives wood its well-known mechanical properties. It is easy to split lengthwise, but not across, because the cells can be forced apart in the one direction and must be cut through in the other. It is easier to saw across than with the grain, because in the latter case the saw tends to tear the fibres and have its teeth tangled by them. The 'grain' of the wood is just the run of the cells.

But these cells are not all of one kind. Most important are the **wood-vessels.** These are very wide cells joined end to end. Furthermore the end walls have disappeared during growth, so that one cell is continuous with another; sometimes for a distance of many feet. The whole vessel is exactly like a water-main built up of iron pipes jointed together. And the wood-vessel is just a water-pipe. The longer it is (without a cross-wall), and the wider it is, the better it works, for the less is the resistance it offers to the flow of water through it. So we find that when water has to be transported a very long way, very long, wide wood-vessels are found. The lianas of the tropical forests are climbing plants which raise the leaves to great heights, with a thin twining and scrambling stem, and in these we find the biggest of all wood vessels. The oak is a tree with vessels so large that in a cross-section of the wood they can be seen like little pin-pricks. It is in these that the death-watch beetle (q.v.) which destroys oaken beams lays its eggs. Wood vessels are not very strong. Their walls have been changed in the course of their development into wood by impregnation with various obscure chemicals. They are strengthened by bands, rings, spirals, and networks of thickening. But the strength probably is more important in preventing them from being crushed, than in adding to the total strength of the wood of which they form only a part, and not usually the largest part.

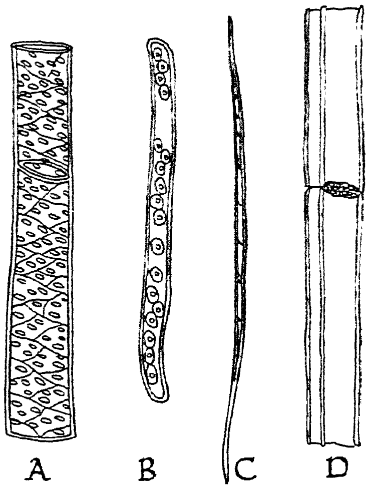

FIG. 412. ELEMENTS OF THE WOOD AND BAST

A, wood-vessel. B, tracheid. C, wood fibre. D, sieve tube and companion cells.

A second element of the wood is the **tracheid.** This is a long cell, not so wide as the unit of the wood-vessel. It is rather pointed at the

ends, and it remains as an independent unit and does not lose its end walls. It, too, is dead and empty. Its walls are more uniformly thickened than those of the vessel, but in them oval or circular patches remain thin; these are called **pits.** The thick wall, of course, means strength; the thin places allow water to pass more readily from one cell to another than it could do if the whole wall were thick. The cell-wall of vessel and tracheid, then, is a compromise between strength and penetrability. In the vessel the balance inclines towards the latter, in the tracheid towards the former. The tracheid is more important than the vessel in giving strength, it is much less efficient in carrying water.

Vessels are found only in the flowering plants. The wood of the conifers is built up entirely of tracheids. In the conifers the tracheids are particularly wide, and their pits are large and very numerous. But even so the wood of a pine is far less efficient than that of an oak: the oak stem can conduct water at least six times as rapidly as the pine. There is no doubt that one of the chief causes for the dominance of the flowering plants on the land surface is that they have evolved this highly efficient system of water-conduits. The ferns and their allies too depend on tracheids, though in some ferns there is a beginning made in connecting one tracheid to the next by narrow openings.

The third element of the wood is the **wood fibre.** It is usually longer than the tracheid, narrower, and with very pointed ends. Its walls are so much thickened that there may be little cavity left, and the pits are mere slits. It has no importance in carrying water, but it is the chief source of strength. Most of the wood of the oak is made up of closely packed fibres, and to this it owes its hardness, strength, and durability. The pine wood has no fibres, and in consequence is softer, and much less strong. In the mosses the water-conducting elements are more like fibres than tracheids, though their walls are not very thick. Consequently the moss has the least efficient water-conducting system of all the land plants. It is of great interest to see how the internal structure has altered with the evolutionary ascent of the land flora, leading to an ever greater efficiency in dealing with one aspect of the great water problem.

These three types of elements are all dead when the cells reach maturity, but wood contains living cells as well. Some of these are short cells lying in vertical rows, and have woody, pitted walls. Their chief function is to store food, usually in the form of starch. Perennial plants all store food over winter, the potato in its tubers, the carrot in its roots. The wood of the tree adds to its other functions the rôle of storehouse, and so densely may it be packed with starch that it turns black when touched with iodine. The most prominent of the

living cells in the wood are, however, those of the **medullary rays** These are bands of tissue which run from the centre towards the circumference of the tree trunk, and they may readily be seen as narrow radiating lines on the stump of a felled tree. The cells which compose them are short cells running horizontally between the vessels and fibres, and built up into bands, sometimes an inch or more in depth. They resemble little brick walls running across the wood. It is the presence of large medullary rays which produces the beautiful silken grain of the oak when it is cut on the quarter so as to expose the surface of the rays. These rays are the chief channel by which food substances (and water) travel across the wood from outside to inside, and vice versa. They also serve to store starch.

The wood of a flowering plant is thus a very complicated tissue doing three kinds of work. It is an admirable example of how the cell, changing its form, is suited to very different functions, and of how, by a combination of different types of cell, a tissue may be used in several different ways.

The epidermis of a young twig is like that of a leaf, and has stomata. Within it lies a **cortex** of green chlorophyll-containing cells which do a certain amount of food-building. Within this, and outside the wood, is a further tissue which cannot be distinguished by the naked eye, the **bast** or **phloem.** It includes long rows of cells arranged end to end like the units of a wood-vessel. These cells are, however, living, with a protoplasmic lining, and their walls are not lignified. The end walls are pierced by a number of pits in such fashion that on viewing them from above they look like sieves. They are called **sieve tubes.** They have to perform the important function of conducting the organic food material, sugar, and proteins, from the leaves to the other parts of the plant. Between them stretch extensions of the medullary rays, and along these rays food material passes into the wood where it is stored for future use. In the bast, too, there are strands of woody fibre cells. It is these which make the rind of many trees stringy. So well developed are they in the lime that bast fibre used to be made from the rind of that tree. Such fibres in the flax are the source of linen.

All the tissues we have described are mature and some of them dead. They are incapable of growth. Now we know that a tree increases in girth from year to year. This is accomplished by a growing tissue, the **cambium,** which lies as a thin cylinder between wood and rind. The cambium is very thin and can be seen only with a microscope. But its presence is very obvious in spring time when it is most active. Its cells then become full of water, and, as their walls are delicate, they tear easily. So it comes that in spring we can easily strip the rind from the wood, leaving the latter moist and glistening from the contents of the ruptured cells. So the country lad strips the rind from a

mountain ash to make a whistle. The cambium grows by the division of its cells to form new elements. Those it forms to the inside mature into new woody tissues, those to the outside into new bast. The structure of the wood varies with the time at which it is formed. In spring and early summer the tendency is to form many and large vessels and few fibres. In later summer the vessels are fewer and smaller and the fibres more abundant. The formation of vessels in spring meets the needs of the plant, for then a good supply of water to the bursting buds is a first necessity. It is this change in the structure of the wood which leads to the formation of the **annual rings** so clearly seen on a cut stump. The denser wood of autumn stands out clearly from the looser wood of spring. Even in the pine, where there are only tracheids, the annual rings are clear, for the autumn-formed tracheids are smaller and have thicker walls than those of spring.

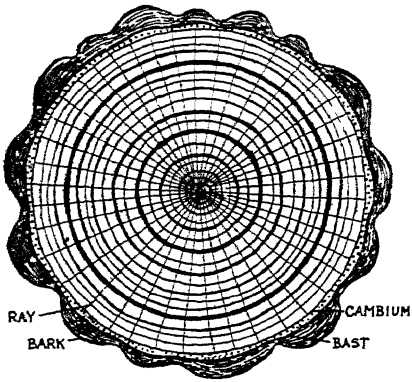

FIG. 413. DIAGRAMMATIC CROSS-SECTION OF TREE TRUNK

By counting the annual rings we can tell the age of a tree with great accuracy, so long as the heart has not rotted away. The wood in the centre of many trees undergoes a change with age. The vessels become blocked by ingrowths: the cells become impregnated with resin and tannin; they lose their power of carrying water. So is formed the dark-coloured, strong **heartwood** of such trees as the oak.

It will be obvious that as the wood increases in girth it will tend to burst the outer rind. That it does so is seen in such trees as ash and pine with their fissured barks. Yet the rind maintains a continuous covering. This is made possible by the formation of a new tissue called **cork.** Near the outside of the cortex in the first year of growth of a woody twig there appears a second kind of cambium, the **cork cambium.** The cells of this also grow and divide, forming new cortex inside and cork cells to the outside. The cork cells are flat empty cells with their walls waterproofed by a waxy impregnation. As these cells are dead and impervious to water, the tissues outside die and are sloughed off. The outside of the twig is thus covered, not by an epidermis, but by a layer of cork. Aëration of the internal tissues is provided for by little oval patches of loose cells, which can be seen with the naked eye as lighter-coloured patches on most twigs. As the twig or branch grows in thickness a new cork cambium is formed within the first one, and the

process is repeated. The dead masses of tissues to the outside crack and are gradually cast off. **Bark** is thus dead tissue, showing the fissures caused by the force of the expanding wood. Always within it there is a layer of cork recently formed and completely protecting the living tissues inside. Usually these layers of cork are quite thin, but they may be very thick. The formation of thick cork enables us to obtain the cork of commerce from the cork oak.

The Root

The tissues of the root are essentially like those of the stem, but we must refer to some special features. A root in its youth, the radicle of a seedling for example, forms no cuticle. Its function is the absorption of water, and it lives in water-saturated surroundings. It need not guard against water loss, and it must be able to absorb water freely. But even more efficient arrangements are made for water absorption than this negative quality. Near its tip the young root bears a covering of hairs. Each is a prolongation of an epidermal cell into a fine tube, perhaps a quarter of an inch long; its cavity is continuous with that of the parent cell. Root-hairs may be seen beautifully in cress seedlings germinated for a few days on damp blotting-paper. In the soil the hairs, thousands in number, enter the most minute crevices and mould themselves to the grains of mineral matter, drawing thus on the delicate water-films which surround them. The actual surface through which water may be absorbed is enormously increased, and the most intimate sort of contact is made with the soil. Root-hairs are usually short-lived. As the root grows it forms new hairs, and those behind die off. The older root becomes covered with a tissue impervious to water, and serves to carry but not to draw in water. That is the function of the young parts pushed out in all directions through the soil as the root system branches and extends.

Architecture

The trunk of a tree is an almost solid mass of wood with a very small central cavity where the pith once was. The structure of herbaceous plants, however, seldom follows this plan. A plant which springs up in a year and then dies down makes a deal of rapid growth. It cannot build up a great column of wood to support its frequently heavy foliage. It requires an adequate water - conducting system, and vessels must be produced in quantity: the amount of fibre is often small. A little must be made to go a long way. The engineer, when he has to plan the girders of a bridge or the columns of a steel building, must also make a little go a long way. A principal part of his job is to distribute

his material so that it may give the greatest strength. And one great principle is that, if a bending force is to be resisted, the material should not be gathered in a central mass. A hollow column will bend much less readily than a solid one containing the same amount of material. In most herbaceous plants we find this principle followed. The pith, or the cavity left by its disappearance, is wide, and round it stands a relatively thin-walled column of tissue, including, of course, the wood. The central cavity of the stem of the cow-parsnip, or sunflower, or the straw of an oat, is far larger relatively—or even absolutely—than that of a full-grown tree.

In the stems of herbaceous dicotyledons the wood does not, at least at first, form a complete cylinder. It is present as separate strands arranged, as seen in a cross-section, in a circle of dots. Later on the activity of the cambium may build up a complete hollow cylinder. But before this happens the circle of strands acts like a series of girders. The girder principle of structure is another ingenious device we find repeated in the plant. Two flat plates of steel are united by a cross-plate, set at right angles to them. In the plant a more complex arrangement is normal, for each pair of opposite bundles, embedded in the softer tissues, acts in effect like a girder. Additional strengthening tissue is often provided. The dead-nettle has a square stem, and down each angle runs a strand of special mechanical tissue. The two diagonally opposite strands function as girders.

In the monocotyledons we find special types of construction. They differ from the dicotyledons in lacking a cambium and having very little growth in thickness. Monocotyledonous trees with thick stems are rare, and their growth in thickness is different in method and less efficient than that of dicotyledons. In the monocotyledon stem there are often very numerous bundles, each consisting of wood and bast, often associated with strengthening fibres. Frequently these bundles are scattered all through the stem. Very often the hollow-cylinder type of construction is arrived at by the production of a ring of fibrous tissues running round the stem just under the epidermis, or some little distance in. Frequently, too, this ring is strengthened by fibrous strands projecting from it outwards.

In roots, the force to be resisted is the strain of a pull and not the stress of bending. The best mechanical analogy is that of a rope or cable. Here the material is concentrated, instead of being dispersed. In roots we find the woody tissue massed in the centre, and often a complete absence of pith. In trees the main roots running from the base of the stem gradually thicken upwards, so that their bases, lying above the soil, run out from the trunk and act as buttresses. In certain tropical trees the buttresses run for yards up the trunk in the form of thin planks. Sometimes roots grow from near the base of the stem and

arch outwards before entering the soil. These *prop roots* also act as buttresses, and they produce mechanical tissue on the hollow-cylinder plan. They may be seen in the maize, and are specially prominent in a curious exotic group of monocotyledons, the screw-pines.

The leaf has its own mechanical problems. It must spread out flat, and it must resist the tearing action of the wind. How successful it is in this is evident from the easily observed fact that leaves brought down in a gale are not usually otherwise damaged. It is easier to tear a leaf from a tree than to tear it in two. The epidermal cells around the edge are specially thickened on the outer walls and form a strong rim much in the fashion of the hem of a garment. Lobed leaves have particularly strong epidermal cells, or even groups of fibres, in the bays of the lobes, and these act as gussets to protect the most vulnerable parts. In running water leaves usually survive unimpaired by avoiding rather than resisting the current. They are often cut into narrow segments, as in the water-milfoil, and this, combined with lax stems, allows the water to flow easily over them. The long narrow leaves of grasses frequently possess internal girders of fibres which enable them to stand upright. Such leaves are frequently twisted on their axis, and this gives increased rigidity.

Very large leaves can hardly be sufficiently strengthened to resist tearing. Very often they are cut into smaller segments, as in the hemlock and other *Umbelliferae*. Palm leaves are naturally torn during their development. The enormous leaves of the banana do not survive their year's life without being tattered by the wind.

The maintenance of a flat expanded surface in the leaf is brought about by other means. The mechanical network of the veins of course helps. But soft leaves, when they lack water, wilt, droop, and crumple up. Their proper stiffness is due to the internal water pressure or **turgor pressure** of the cells. Though the *wall* of a cell may be quite soft and pliable cellulose, the *cell* is not flaccid. It is inflated with water, and hence becomes rigid or turgid. A child's sausage balloon, when deflated, is completely limp; when blown up it stands out stiffly in its own shape. So with the plant-cell: when it has insufficient water it collapses, when it is fully supplied it is taut. And the multitude of taut cells give tissues a very considerable rigidity. This is well seen in a celery-stalk, which when crisped by standing in water breaks before it bends. Young stems, and especially leaves, owe most of their rigidity to this internal process. When they lack water they droop. Only later in life, when fibrous tissue has been built up, is the stem independent of turgor. Here we see how the living cell, by virtue of its power of drawing in water, can, fulfil the function of securing rigidity.

THE LIFE OF THE PLANT. (1) NUTRITION

Photosynthesis—The proteins: nitrogen-supply—Mineral nutrition—Respiration: the supply of energy—Excretion—Irregular nutrition—Parasites—Insectivorous plants—Water problems—Transpiration—Root systems.

THE life of the plant as of the animal is active, it is a story of doing things. What sort of things does the plant do? The most important thing any organism does is to *feed*. The capacity for nutrition, for taking in matter from the external world, and turning it to its own use, enables the plant not only to build up its own body, but to produce the supply of energy it requires, less obviously than the active animal but not less absolutely. Thus the plant *grows* and *develops*. Organic growth is not mere increase in size, it is rather the orderly change of form which leads to the development of the adult from the embryo and of the embryo from the fertilized egg. In growing the plant *moves*, and it moves its organs to other ends than merely to increase its height. The movement is often regulated by external conditions, as when the geranium bends towards the light, and this shows that the plant is *sensitive* to the impact of the external world and can respond to it advantageously; it is *irritable*. And finally, at the end of its development, and, in many plants periodically throughout life, it multiplies itself by *reproduction*. We may sum up by saying that the five great functions of the plant are **nutrition, growth, movement, irritability,** and **reproduction.**

Our food consists of organic matter, ready prepared for us by other animals or by plants. In all its variety it reduces itself to three fundamental classes of organic compounds: *carbohydrates* (starch and sugar), *fats* (and oils), and *proteins*. The normal plant contains all these, but draws none of them from external supplies. This is its peculiar property, to be able to build them up for itself from simpler inorganic substances.

PHOTOSYNTHESIS OR CARBON-DIOXIDE ASSIMILATION

Organic matter is so called because in Nature it is always associated with living organisms. The basis of the compounds is the element carbon, familiar in nearly pure form in good charcoal, and, purer still,

as diamond. Sugars, starch, and other organic matter char when overheated, and the charring is simply due to the loss of other constituents, largely water, and the freeing of the carbon. Many organic compounds, e.g. carbohydrates and fats, consist entirely of the three elements, carbon, oxygen, and hydrogen. That from these three there can be built up an astonishing variety of compounds is due to the fact that the carbon atom can combine with *four* atoms of hydrogen or *two* of oxygen. Two carbon atoms can unite, and each is still able to unite with three atoms of hydrogen. Some compounds are built up of long chains or rings constructed on this plan; others show an intricate variety in the pattern in which their constituent atoms are arranged. The proteins always contain much nitrogen in addition, as well as a small proportion of phosphorus and sulphur. With so small a number of elements—the number of elements existing in the inorganic world is about ninety—all the wonderful variety of organic compounds is constructed. It used to be thought that organic compounds could be built up only in the bodies of living things. But in 1828 Wöhler synthesized urea in the laboratory. Since then chemists have built up a great variety of these substances, even such complex ones as the sugars.

The formation of the organic matter in living things begins with the process of carbon-dioxide assimilation. The gas, present in ordinary air to the extent of about 3 or 4 parts in 10,000, passes through the stomata into the leaf, through the internal air-spaces to the palisade-cells, and then, in solution, to the chloroplasts. There it is made to react with water to form carbohydrates, such as sugar, while oxygen is liberated and returned to the air. The process takes place only in presence of the green pigment **chlorophyll,** and under the influence of light. To understand why light is necessary we must realize that, to liberate oxygen from carbon dioxide, a supply of energy is necessary. When sugar burns it absorbs oxygen from the air and is turned back into carbon dioxide and water. But something besides these two substances appears, and that is *heat,* a form of *energy.* To carry out the reverse process, and change carbon dioxide and water to sugar and oxygen, the plant must, as it were, replace the energy. It does not use the energy of heat but of *light* to this end. The rôle of the chlorophyll is the absorption of the necessary light.

Why is grass green rather than some other colour? All pigments absorb light, and black absorbs it more efficiently than any other. The plant, in this as in many other matters, must compromise. If it were black it would, under some circumstances, absorb so much energy, especially the strong yellow rays, as to harm itself by overheating. Green largely avoids this danger: also it absorbs both blue and red light. Blue is predominant in light from the sky, in diffuse

light. Red is predominant in light from the sun, especially when it is low in the sky. Thus green avoids, as far as may be, the danger of absorbing the heating rays, and yet makes good use of the light falling on it both from the sky and from the sun. We have already noted that the colour of the red seaweeds is related to the blue light in which they live. The red pigment of a copper beech or purple cabbage has nothing to do with assimilation. It is present in solution in the watery sap of the vacuoles and merely masks the green colour of the chloroplasts, which are as usual present in the cells of these plants. It is doubtful if it has any use.

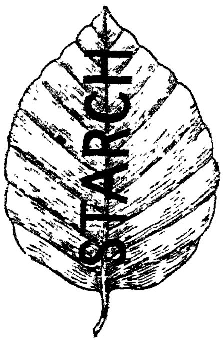

FIG. 414. THE FORMATION OF STARCH IN LIGHT

A leaf is exposed to light under a stencil. In the evening it is bleached and treated with iodine. Only in the illuminated parts does the black starch reaction appear.

The discovery of the process of carbon assimilation (also called **photosynthesis** because of the part light plays in the building-up or synthesis of organic compounds) is an interesting chapter in the history of science. Joseph Priestley, the great eighteenth-century chemist, chanced on it in his search for the means by which air is made 'good.' He knew, though his chemical language was different from ours, that combustion and respiration were continually pouring carbon dioxide into the air and thus making it 'bad.' There must be some counter-process, for the pollution was not cumulative. This he found in the activity of plants in the sunlight. Later investigators realized the importance of the process in the nutrition of the plant, and an ancient puzzle was solved. For till then no one knew where the plant obtained its substance, though most people thought it was from the soil.

The sugars formed in carbon assimilation in the leaf are passed back along the sieve tubes to other parts, to the growing points, where they contribute new material, and to the storage organs. Often so much sugar is formed that it cannot be removed sufficiently fast, and then it is changed into starch grains which accumulate in the leaf by day and disappear through the night. So much starch is formed in a day that if a leaf is taken in the evening, bleached in methylated spirits, and dipped in iodine, it turns black.

Starch is an insoluble compound, and before it can be transported it must be converted into soluble sugars: in fact the plant must digest insoluble food just as we do. It does so with the aid of a group of substances called **enzymes** or ferments, which have the property of causing extremely active chemical change. An enzyme, **diastase,** similar in its action to the **ptyalin** excreted by our own salivary glands,

has the property of changing starch into sugar. It occurs in leaves and in other parts of the plant, and is specially abundant in germinating seeds, where it makes the starch available for the growth of the embryo. When barley is *malted*, its diastase is allowed to act on the stored starch long enough to convert it into malt-sugar; it is then killed by heat, and, when mashed with water, provides the sugary solution the fermentation of which by yeast yields beer.

The activity of the process of assimilation is very great. A leaf the size of this page may be able to make, in the course of a day, only one-sixtieth of an ounce of sugar; but that is half an ounce in a month, or a quarter of a pound in the course of a season. If we try to estimate the activity of plants in the mass, we find it very impressive. A field of wheat builds up dry matter at the rate of about five tons per acre in the growing season—a hundredweight a day at the height of growth. Forest trees are more active, and the yearly addition to an acre of beech-wood may reach fourteen tons. Very large quantities of light-energy are used in the process. But the sun is a generous source and it is reckoned that, of the solar energy which falls on the earth, only one-hundredth is absorbed by plants, and of this only one-hundredth is used in carbon assimilation.

The Proteins: Nitrogen-supply

The fundamental substances in living matter are the proteins, a varied chemical group most familiar in albumen or white of egg. In wheat flour there are five different classes of protein. The proteins have the peculiar property of acting as either acids or bases according to conditions, and this makes them peculiarly sensitive to change in the environment. They have great powers of absorbing and retaining water. They represent the chemically active and sensitive basis of life. Their characteristic element is nitrogen, and so it comes about that a supply of nitrogen is necessary to the plant—the animal can utilize only proteins already built up for it.

Four-fifths of the atmosphere is free nitrogen, but the gas is chemically inactive and cannot be used by green plants. They obtain their supplies from the soil and, most conveniently, in the form of **nitrates.** Salts of ammonia may also be used, though they tend to be poisonous; in the soil, however, they are rapidly converted by bacteria into nitrates and so become fully available. The soil is normally nitrogen-hungry, for nitrates are not, as many other minerals are, absorbed and held by it: they are washed down by rain and pass with drainage-water into the rivers and sea. In cultivation the first essential of manuring is to keep up their supply, and to this end the farmer adds farmyard manure. This is rich in urea and ammonia, both of which

are converted by bacteria in the soil to nitrate. Ammonium sulphate, a by-product of the gasworks, and Chile saltpetre (sodium nitrate) from the deposits of South America, are used as artificial manures. It will be noted that all these are products of organic activity. The ammonium sulphate is obtained from coal, and the nitrate beds are the result of prehistoric seaweed beds or accumulated animal excretion in a hot climate. Some forty years ago Sir William Crookes foretold that within a generation or so the nitrate-supplies of the world would be so curtailed that further increase in crop production would be impossible. But to-day the chemist can 'fix' the nitrogen of the air, converting it artificially into ammonia or nitrates, and this immense store is now available for the farmers as necessity shall require.

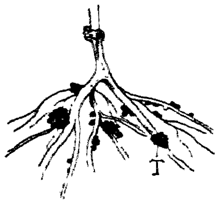

FIG. 415. ROOT SYSTEM OF PEA, SHOWING BACTERIAL NODULES AT T

The various changes which take place in the nitrogen-compounds in the soil are of the first importance to plant life, especially in natural conditions where no artificial supplements are available. The excreta of animals and dead remains of animals and plants are washed into the soil or dragged in by earthworms. Nitrogenous compounds are decomposed by bacteria and yield ultimately ammonia in the form of various salts. The salts of ammonia are oxidized by a special group of **nitrifying bacteria,** first to nitrites, then to nitrates. These may be absorbed by the roots of higher plants and so re-enter the cycle of life. There are two causes of loss. Nitrates may be washed out in drainage-water, or they may be decomposed by another class of bacteria and returned to the air as gaseous nitrogen.

There is thus a constant drain on the available nitrogen of the soil, which would have been exhausted long since were there no further source of supply. There are, however, two. Minute quantities of nitrates are formed during the electrical discharges of thunderstorms and enter the soil with rain. This supply is small. There exists in the soil a third class of bacteria, the **nitrogen-assimilating bacteria,** which are able to fix the free gaseous nitrogen of the air and ultimately make it available for other plants. Certain nitrogen-fixing bacteria inhabit the little nodules which may be seen on the roots of a pea or bean plant, and supply their host directly with combined nitrogen, in exchange for the carbohydrates with which they nourish themselves. This habit is exhibited by all leguminous plants and some few others, such as the bog-myrtle. The plants are thus enabled to succeed on very barren soils, and their dead remains enrich the soil for other plants. The ploughing-in of vetches and of lupines to act as manure is a practice which stretches back to antiquity.

Fungi that inhabit the roots of the heaths have the same power of fixing free nitrogen, though to a less extent. In Nature, then, there is a constant circulation of nitrogen-compounds from the soil to living plants, then to animals, and from them by their excreta and dead remains back to the soil. There is a constant dead loss through drainage-water, and, on the average, the balance is just maintained by the nitrogen-fixing bacteria and fungi.

The nitrates enter the plants by the root-hairs and are carried by water currents through the wood to the leaves, and there, in combination with organic material supplied by the sugars, proteins are built up. The synthesis of proteins does not require the energy of sunlight, and indeed takes place also in non-green parts of the plant and in the dark; probably it is most vigorous in the leaves because organic compounds in the first stages of synthesis are there available in abundance.

Mineral Nutrition

As well as nitrates the plant draws several other kinds of salts from the soil; compounds of *potassium, magnesium, iron, calcium, sulphur,* and *phosphorus* are all necessary. Unlike nitrates these are all derived from the rock débris, which is the foundation of the soil structure. Slowly the water of the soil dissolves away the hard mineral matter, and from the weak solution so formed the plant obtains its requirements. When we burn away plant material, a small amount of ash (about one-fiftieth of the total weight) is left, and this represents the minerals absorbed from the soil. That it is rich in potash we know, for it was 'pot-ash' from which our ancestors obtained the alkali for soap-making.

The supply of these minerals in the soil is largely maintained by the return to the soil of dead plant and animal remains. When we grow crops and remove them from the farm, the soil is robbed of part of its material, and again manuring is required to maintain its fertility. The principal fertilizers added, in addition to those supplying nitrogen, are *potassium salts,* as kainite and sulphate of potash; *phosphorus* in the form of bone-meal, guano, and basic slag; *sulphates*; and *lime.* Slaked lime is calcium hydroxide, but its use extends far beyond the addition of calcium. Lime neutralizes excessive acidity, it lightens heavy clay soils, and it promotes the activity of useful microorganisms. The addition of such artificial manures not only maintains the fertility of the soil, but enables it to bear far heavier crops than it naturally would.

The rôle played by the various minerals in the life of the plant is not always understood. Phosphorus and sulphur are necessary fo

building up proteins. Magnesium is a constituent of chlorophyll; indeed, in the absence of magnesium, chlorophyll cannot be formed. Iron plays an important part in many chemical reactions. Its presence is necessary to the formation of chlorophyll, though it itself is not a constituent of the pigment. The inability of such plants as the heather and the rhododendron to absorb iron from soils containing much lime is responsible for the fact that they cannot make sufficient chlorophyll, become yellow and unhealthy in colour, and do not thrive on calcareous soils. The part played by calcium and potassium is obscure, but their absence leads to general unhealth and failure to grow properly.

Recent researches seem to show that in addition to the normal elements plants absorb minute quantities of organic substances of unknown nature from the soil, and that these are essential to normal growth, or at least greatly increase growth-rate. It is possible that their action corresponds to that of the vitamins which we now know to be so important in animal nutrition. Furthermore, some plants at east require minute traces of minerals such as manganese and boron for proper growth.

Respiration: The Supply of Energy

With the organic compounds built up from inorganic raw materials the plant supplies the needs of its own growth as well as those of the whole animal kingdom. It is well to speak of the material absorbed from soil and air as *raw material*: the true food of the plant consists of the fats, carbohydrates, and proteins which it manufactures. The whole of this food is not used up in the construction of cell-walls, and protoplasm, and the laying down of reserves. Like the animal the plant **respires**, though unlike the animal it does not actively *breathe*. The oxidation of organic compounds in the intimacy of the cell, which leads to a production of energy and a liberation of carbon dioxide, is common to both kingdoms. In the green plant by day the process is entirely masked by the opposite reaction of carbon assimilation, which is much more vigorous. Non-green parts of plants (and, in the dark, the green leaf as well) absorb oxygen through the stomata, use it in respiration, and exhale carbon dioxide.

Respiration is a process of slow combustion: in essence it is the same as the burning of a log of wood. In it organic compounds are consumed and heat is liberated. The organism avoids the violence of combustion: the nicely regulated action of its oxidizing enzymes controls the rate of the reaction. The need for this production of energy is clear in animals with their active movements and their high body-temperature, but not so obvious in plants. Yet if we consider the crown of a tree

we may realize that a great deal of energy was necessary to lift so great a weight to so great a height; the slowness of the process alone disguises its magnitude. We may see the roots of a tree lift up paving-stones. The slow movements of roots in the soil and of leaves to the light all require energy. Underlying all this is a fundamental necessity: for, to maintain the living protoplasm in the state of nice balance in which alone it can function and remain alive, there is required the continual application of controlled energy. It is almost as if a spring of some inconceivably intricate nature were constantly unwinding itself and as constantly being rewound.

Many plants obtain energy in somewhat different fashion. The alcoholic fermentation carried out by the yeast is a breaking-down of sugar to alcohol and carbon dioxide without oxidation. The two substances are at a lower energy-level than the sugar, and consequently energy is liberated in the process: not so much as in the complete break-down by oxidation, so that the process is a wasteful one. But the yeast, living in the rich sugar juices of fruits, can afford to be wasteful, and the alcohol it forms helps to exclude other micro-organisms from a share in its food. Germinating seeds, if deprived of oxygen, can ferment instead of respiring, though this fermentation cannot go on for long without damage ensuing. The higher plants must have oxygen to live.

Matter in the body of plant and animal alike is in continual chemical change, and this flux we call **metabolism.** It runs in two directions: uphill when more complex substances are formed and energy is used up: downhill when organic matter is decomposed and energy is liberated. The chemistry of the plant has fundamentally an uphill trend. The plant is the accumulator which stores energy to the benefit of all life. Yet in it too organic break-down is necessary. Only for one specialized reaction, the formation of sugars, can it utilize external energy. For all its other requirements it must make use of that available in the carbohydrates it has itself constructed.

Excretion

When the leaves fall from the trees in autumn there must be some elimination of waste-products, but apart from this periodic shedding of dead organs do ordinary plants get rid of nitrogenous waste-products? In other words, do they excrete? Until recently it has been usual to answer this question in the negative, and it has been pointed out that plants are not very energetic and will therefore be less likely to be troubled by the accumulation of waste. Moreover, if we rule out exceptional cases, such as the interesting insectivorous plants and such as the *Leguminosae*, which are able by means of partner bacteria

to tap the supply of free nitrogen in the air, we must admit that ordinary green plants are as likely to suffer from nitrogen deficiency as animals, especially carnivores, are likely to suffer from nitrogen excess. The ordinary plants have to find their nitrogen-supply in the nitrates and the like, usually somewhat sparsely distributed in the soil.

But a more precise biochemistry has changed the botanist's view. Urea itself has been demonstrated in a number of plants; allied substances like asparagin, glutamin, and allantoin are of frequent occurrence; and there are several ferments like urease that act on nitrogenous compounds and liberate ammonia. On general grounds, furthermore, since living is bound up with the metabolism of proteins, and since the breaking-down of their components, the amino-acids, involves the formation of ammonia, one would expect plants to have to face the problem of dealing with waste ammonia. They have solved it in a way of their own; they lock up the ammonia in harmless combined form in such substances as asparagin and glutamin. In many a fungus the same rôle—of taking the poisonous edge off ammonia—is discharged by urea itself. The plant's solution is even better than this, for ferments like urease and asparaginase can set the ammonia free again when it is needed for the building-up of fresh protein substances. Thus the plant is physiologically more economical than the animal, for it can use its waste-products as a nutritive reserve. Not merely beauty for ashes, but food out of ashes! Of course this requires a masterly regulation of the prison doors, now shutting up ammonia and again setting it free, but the inmost secret of life is regulation.

Irregular Nutrition

Among the flowering plants a certain number have left the straight and narrow way of nutrition by photosynthesis and have succeeded in supplementing or replacing this source of organic matter by other methods. It is not a case of a branch of flowering plants departing from the main road, as the fungi have departed from the algae. Here and there throughout the system a family, or a group of genera, has adopted another mode of nutrition, has become saprophytic or parasitic or insectivorous. Saprophytes are not numerous. In the British flora the bird's-nest orchis, the coral-root, and the bird's nest (which belongs to the Heath family) are examples. They live in soils rich in humus, and they are assisted in assimilating this by their association with mycorhizal fungi. In appearance they differ much from the normal. They have lost their chlorophyll and are dirty brown in colour. Their leaves are reduced to scales. In fact they are reduced to an absorbing root and a flowering shoot.

PARASITES

Parasitic flowering plants are much more numerous and much more varied. The problem of attacking other plants and drawing food from them has been approached in several different ways. The dodders (*Cuscuta*) belong to the *Convolvulaceae* or Bindweed family. Like the bindweeds they twine round other plants. From the inner side of the coils they send little suckers into the host, and these, making contact with the wood and the bast, draw in supplies of both food and water. The dodder, a species of which may often be seen on the Surrey heaths growing on heather and thyme, consists of a yellow stem with minute scale-leaves. It bears many bunches of little flowers, bell-shaped like those of its free-living relatives. Some species form a little chlorophyll, but never enough to nourish themselves with. The clover dodder may be a serious pest, for it spreads with great rapidity by branching stems, and literally smothers considerable areas of its host. It is easy to see the opportunity that has been seized by the dodders. Descended from twining plants, they have been able to make a more intimate contact with the plants used as supports, and have finally become completely dependent on them.

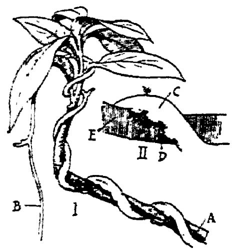

FIG. 416. *Cuscuta*, THE DODDER

I, dodder, B, twining round stem of host plant, A. II, section showing parasite, C, with suckers, D, penetrating the tissues of the host, E.

Another instructive group is that of the broomrapes (*Orobanche*) and toothworts (*Lathraea*). They make contact with the *roots* of their hosts; their aërial shoots are simply flowering shoots, with but a few scale-leaves, and they, too, are quite devoid of chlorophyll. Belonging to the same family, the *Scrophulariaceae*, are a number of other root parasites which are less dependent. The eyebrights, the cow-wheats, the red and yellow rattles are all parasitic on the roots of grasses and other plants among which they grow. But they still have chlorophyll and some of them can still grow independently. They draw salts and water from the host plants, and can assimilate for themselves. They are plants the roots of which, growing in a mass of other roots, have seized this opportunity to begin a parasitic existence. Some have not gone far in their parasitism, but the broomrapes have arrived at the completely dependent state.

The Mistletoe family (*Loranthaceae*), which has a great many species growing in tropical forests, though only one occurs in this country, lives predominantly high on the branches of trees.

Very early in our history the mistletoe of the north—for there are

scores of different mistletoes—became a seasonal symbol, indicating the deadly power of winter. Balder the Beautiful was the vigour of life, and to him, according to the pact, no thrusts and arrows could do any hurt. But as his mother had forgotten to pledge the mistletoe in its unearthly isolation, the evil spirit fashioned an arrow from the slim branch and directed the aim of the blind Höder, the god of war, so that Balder was pierced to the heart. How deeply the story searches—the blind god of war killing vigour and beauty, using the very power of life to bring death and world-sorrow. So do the arrows of winter destroy the glory of summer, until Balder the Beautiful returns in spring. Therefore with searchings of heart let us hang up the mistletoe, for what do we need more than insurgent life?

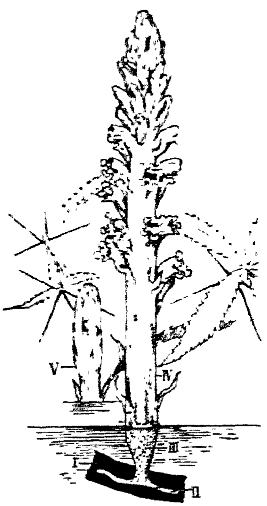

FIG. 417. *Orobanche*, THE BROOMRAPE

I, root of host; II, sucker; III and IV, stem of parasite; V, young shoot of parasite.

The second picture takes our thoughts back to the times of Nature-worship, when the oak tree was sacred to the god of thunder, and the mistletoe the symbol of his lightning. Our mistletoe rarely grows on oaks—rather on apple tree, black poplar, hawthorn, willow, and pear—but all the greater the sacredness of an oak with a mistletoe and of a mistletoe on an oak tree. Thus it was that on the 21st December, the ancient New Year's Day, and also at midsummer, the white-robed priests went forth with golden pruning-hook to cut the golden bough. Pliny tells us how it was caught in a white web to prevent all touch of earth; and that is why we *hang* our mistletoe. It was hung from the roof-beams long ago, as a talisman against evil, and as an acknowledgment of the power of the gods, who were apt to be jealous of human happiness. And that is why people who are very happy to-day will kiss one another under the mistletoe without being afraid.

A subtle symbol should always be beautiful, and that is very true of the living mistletoe in a Herefordshire orchard. The slow-growing green stem, able to function as a leaf, often has a glimmer of gold; each length, so markedly punctuated by nodes, represents a year's work; the branching is by symmetrical forking or dichotomy; the two opposite leaves on each branch have a pleasant colour and texture; at each forking there are tiny florets in groups of three, succeeded by the more familiar pearl-like berries. There is an artistic touch

also in a great bush of mistletoe a yard across, for the branches of such a veteran spread out in comfortable curves, without all striving upwards and getting into each other's way. The botanists say that the mistletoe is strikingly indifferent to the influence of gravitation

FIG. 418. *Viscum album*, THE MISTLETOE

—which is what we should expect in a plant that has emancipated itself from the earth.

There are a few kinds of mistletoe—out of many scores—which adhere to the old convention of starting life in the ground, and it is rather interesting to find that these have ordinary hard-walled seeds without the viscous pulp characteristic of our *Viscum album* and its relatives. When a missel-thrush, or occasionally some other fruit-eating bird, picks off the mistletoe berry for the sake of the pulp, it does not usually swallow the seed, but wipes it off on the branch. The drying remains of the viscid glue (used in making that atrocity called 'bird-lime') draw the seed close to the bark, and after a period of dormancy there is sprouting and the sinking of suckers into the wood. It may have been through the glutinous character of the

fruit pulp that it became possible for the ancestors of our mistletoe to become wholly independent of the soil. We may mention that the mistletoe seed is sometimes sown *after* having been swallowed by the missel-thrush, but this is exceptional. So is one of the Californian mistletoes, whose fruit bursts with so much violence that the seed is jerked out for a considerable distance.

We may ask the question—what is the exact relation of the mistletoe to its host? The frank answer is that our mistletoe is a little bit of a thief, for it absorbs the indispensable water through the intermediation of the young wood of its host. On the other hand, it has so much green tissue of its own that it can make carbon-compounds for itself like all ordinary plants. To begin with, however, it must be very dependent on its bearer, for it is not till its second spring that the young mistletoe gets its first pair of leaves. Moreover, it is easy to have too much mistletoe, as one sees in many American woods, where a single tree may have over a score of big bunches. Worse and worse, there are leafless mistletoes which have only their green branches to depend on for photosynthesis. But returning to our own mistletoe, bearing which Aeneas went safely through Hades, we plead that it be regarded not as a sinister parasite, but as a handsome adventurer.

Insectivorous Plants

The most curious departure from normality in the whole of plant life is shown by those plants which have taken to capturing and digesting insect-prey. The habit may have started with such sticky hairs as we may see on the flower-stalks of many saxifrages and catchflies. Small undesirable insect-visitors crawling about the inflorescences are caught and prevented from getting mixed up with the pollen. Then some plant may have begun to benefit from the absorption of the products of the decay of the dead bodies, and so the way was opened which has led to the **sundews** (*Drosera*) with their leaves covered with complex hairs performing the function of catching, killing, and digesting the prey.

The Drosera tentacles—rosy, glistening, club-ended hairs—are very sensitive to touch, and to chemical stimulus. A small gnat first sticks in their viscid excretion; then all the hairs of the leaf bend over it, pouring out abundant liquid. In this liquid are protein-digesting enzymes, and all but the husk of the insect is dissolved and absorbed in the course of a few days. The sundews are not wholly dependent on insects for food. They have the power of photosynthesis, and it is probably chiefly nitrogen-compounds that they obtain from their diet of flesh. It has, however, been shown that meat-fed plants thrive

very much better than those which are forced to live the ordinary life of a plant.

In the **butterworts** (*Pinguicula*) we have another group of insectivores belonging to a different family, which are less active than the sundews. The famous **Venus's fly-trap** of Florida (*Dionaea muscipula*), however, has a sensational trap. On the upper-surface of each leaf-half are three stiff bristles; if one of these is gently touched twice the leaf closes, almost with a snap, and the insect or other small animal which has pulled the trigger is held and rapidly drowned and digested by a copious secretion, which is poured out by special glands.

FIG. 419. *Drosera rotundifolia*, THE SUNDEW (left), AND *Pinguicula vulgaris*, THE BUTTERWORT (right)

Our **bladderworts** (*Utricularia*), common submerged plants of moorland pools, have adopted another plan. Many of their leaf-tips are changed into little bladders, each closed by a hinged lid. When a small water-flea touches this lid, or the hairs near it, the lid opens inwards and the animal is sucked into the bladder, where it ultimately dies and rots. From the products of its decay the bladderwort benefits. The same sort of principle on a much larger scale is exhibited by the **pitcher-plants**.

There are many different kinds of **pitcher-plant**, but the finest are species of *Nepenthes*, which have their headquarters in the mountain forests of Malay. Some live on the swampy ground, and have their pitchers more or less buried among the fallen leaves; others are scramblers amongst the undergrowth; but typically they are epiphytes, perched on branches high above the ground, and with their pitchers

dangling in the air, each supported by a tendril-like stalk twisted round a twig. In all cases they are 'nitrogen-hungry' plants, and those that are quite off the ground cannot, apart from their booty, get any nitrates or the like except from the rain-water, and such particles and fragments as may be swept down to the roots on the branch. Hence the importance of insect-catching to these peculiar plants, of which there are about forty different species, with pitchers that vary from the size of a thimble to the capacity of a quart pot!

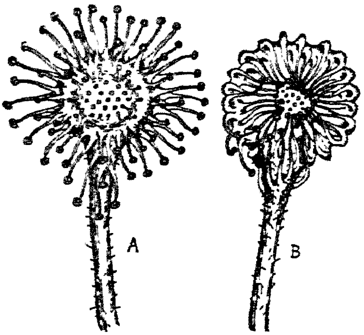

FIG. 420. SUNDEW LEAVES
A, tentacles open. B, tentacles closed after stimulation.

A typical pitcher, whether an inch or a foot in length, is borne at the end of a slender tendril-like prolongation which is continued from the midrib of a somewhat strap-shaped leaf-blade. The pitcher is an extraordinary development of the tip of the tendril, and an interesting point is that a fully formed pitcher does not usually arise unless the tendril portion has twisted round some support. Tendrils that hang loose, having found nothing to twist round, seldom bear more than poorly developed pitchers, and may have none at all. It is not unreasonable to point out that a pitcher full of fluid could not be carried unless the stalk were twisted round a support; but the difficult problem is to trace the sequence of physiological events between the contact-stimulus of the tendril and the extraordinary growth at its tip. In some cases, it must be noted, the pitcher rests on the ground or against an adjacent branch.

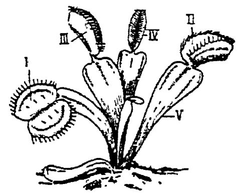

FIG. 421. *Dionaea muscipula*, VENUS'S FLY-TRAP

I, surface view of leaf; II, edge view of leaf; III and IV, leaf closed over insect; V, winged leaf-stalk.

The mouth of the pitcher is, to begin with, closed by a lid, which afterwards opens and arches over the aperture, keeping off the rain. On the anterior or lower surface of this lid there are nectariferous glands, doubtless attractive to insects, which may also be enticed to exploration by bright red patches often developed on the outer surface of the pitcher.

The firm and beautifully fluted rim of the pitcher is turned inwards and downwards, and serves to keep the mouth stiffly open, besides forming a convenient landing-stage for the winged visitors. The edges

of the flutings are often produced downwards into hook-like processes, which may be strong enough to retain a small bird! Furthermore, on this intricately fashioned rim there is a row of very large flask-shaped glands, which are probably attractive.

Just below the rim comes a 'conductive surface,' made slippery with wax, and all the more dangerous because beset with downward-projecting, crescent-shaped processes which the insect-explorer's feet will not readily grip. This makes a *facilis descensus* indeed, and a surface on which it is very difficult for the victim to retrace its steps. It appears that the little crescentic ledges are due to a peculiar transformation of the two guard-cells which open and close the little openings or stomata normally abundant on the under-surfaces of leaves. The ordinary function of these microscopic apertures is to regulate gaseous exchange and the transpiration of water-vapour; but inside the pitcher the guard-cells have ceased to be able to open and close, and one of them has grown downwards over the other, making a little crescent-like ledge. This is a good instance of one of the methods of Organic Evolution, making a new thing out of something very old.

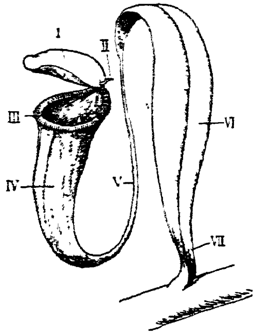

FIG. 422. *Nepenthes*, PITCHER-PLANT

I and II, lid; III, edge of pitcher; IV, pitcher; V, tendril; VI, leaf-blade; VII, leaf-stalk.

Below the slippery conducting zone comes the secretory surface, with numerous multicellular glands. Each projects slightly from a downward-opening depression, 'like a watch just beginning to slip out of an inverted watch-pocket.' These glands, which secrete the abundant fluid—already present in the pitcher before the lid opens—may be thought of as great exaggerations of the water-glands which are found on plants such as the scarlet runner, and to nectaries of flowers. But besides water, the glands secrete, as in most other insectivorous plants, a peptonizing digestive ferment which dissolves the soft tissues of the drowned insects. Along with the ferment there are acids which facilitate digestion and prevent premature putrefaction. In vigorous pitchers, not overweighted with booty, digestion proceeds apart from any bacteria; but these may intervene when the captures have been all too abundant and there is an inadequate acid secretion. Then the contents become rotten in the strict sense of the term. Very remarkable is the occasional occurrence of living animals in the fluid of the pitcher. Nine different species have been recorded, including larval stages of flies, midges, mites, and threadworms. They must have become adapted to resist digestion, just like intestinal parasites in animals.

In some species of *Nepenthes* there are basal or radical pitchers less highly developed than those we have described, and in these the long stalk portion between blade and pitcher does not function as a tendril. These basal pitchers usually rest on the ground, and their booty consists of wood-lice, slugs, and insect larvae. In *Nepenthes melamphora* only the lid of the trap projects above the mould on the ground.

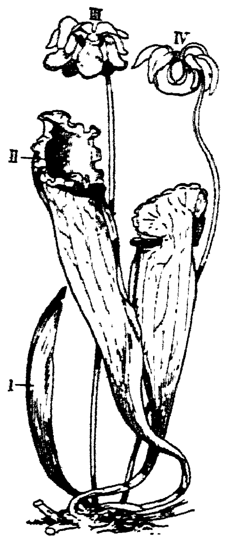

FIG. 423. *Sarracenia*, AMERICAN PITCHER-PLANT
I, young pitcher; II, mature pitcher; III and IV, flowers.

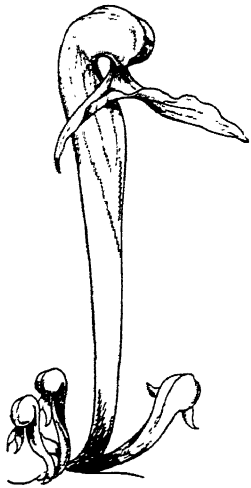

FIG. 424. *Darlingtonia*, CALIFORNIAN PITCHER-PLANT

As the ordinary hanging pitchers, which used to be interpreted as benevolent provisions for the thirsty traveller, are successful in capturing many insects, it is not surprising that they should have attracted the attention of other animals. Thus the sweet-toothed ants come to lick the sugary secretion, and there is a spider that normally makes a web just below the rim of the pitcher. Birds have been seen splitting up pitchers for the sake of the contained insects, and even small rodents condescend to visit the traps. In *Nepenthes bicalcarata* there are two strong spurs, growing from the base of the lid over the mouth, and these are interpreted somewhat generously as adaptations which deter explorers of high standing. But in spite of the spurs the spectral tarsier manages to insert his long-clawed fingers with good effect.

Besides Nepenthes, which is probably the best-disguised leaf in the world, there are other quite different pitcher-plants, such as the trumpet-shaped *Sarracenia* and the small Australian *Cephalotus*, which has ordinary leaves as well as their transformations. It is interesting to notice that in Sarracenia and *Darlingtonia* there is no secretion of ferment or of acid, but simply an absorption of the material rotted by bacteria. In Cephalotus there is no digestive ferment, but there is an acid secretion which hinders ordinary rotting, yet allows specialized micro-organisms to work. All these things are object-lessons in evolution.

WATER PROBLEMS

Of all the raw materials taken in by the plant, water is that of clearest importance. We all know that we must place flowers in water to keep them fresh, and water the garden in dry weather if plants are to remain unwilted and continue growth. Ninety per cent by weight of many plants is water: how light the heap of dried leaves, how heavy the bundle of fresh weeds! All this water must be absorbed from the soil, and it is but a fraction of the plant's requirements. In a season's growth a plant uses many times its own weight of water, and this because, as we have already noted, it continually gives off water-vapour to the air, or transpires. **Transpiration** is the necessary consequence of the exposure of a large leaf surface to sun and wind. Cuticle and stomata keep it within limits, but in ordinary plants it always accounts for very large water losses. Transpiration may help to cool a leaf exposed to the full rays of the sun—as the Italian peasant cools water by leaving it in a porous jar from the surface of which it evaporates. The stream of water through the plant, to supply the leaves, carries with it the salts absorbed from the soil. But, in the main, transpiration is a dead loss, a debit item incurred in providing for carbon assimilation, and the loss must certainly be made good: overdrafts on the water balance cannot long be incurred by ordinary plants without the serious consequences of wilting, withering, and death.

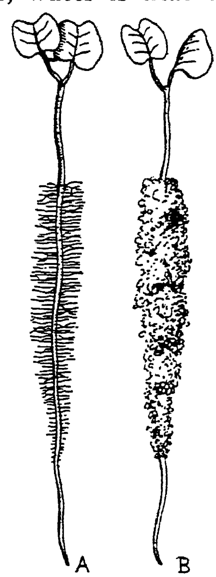

FIG. 425. ROOT-HAIRS
A, mustard seedling grown in moist air, showing root-hairs
B, mustard seedling grown in sand, with grains clinging to the hairs.

The supply of water is maintained by the root system, the growth and branching of which carries the root-tips with their delicate absorbing hairs to every part of the soil within reach. The soil is an admirable medium of plant growth. In its crumbly, porous consistency it is a medium which is penetrable, which is full of air (without which the roots could not grow), and which holds, as films on the surface of its grains, the moisture the plant requires. The absorption of the water is a function of the living cell. By virtue of a strong solution of sugars and other substances in its sap, prevented from escaping by the properties of the protoplasm, the root-hair is able to draw in water and then to pass it inwards till it reaches the wood-vessels through which it is to travel upwards.

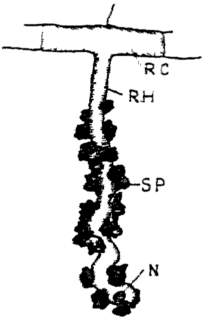

FIG. 426. ROOT-HAIR
RC, root-cell; RH, root-hair; N, nucleus; SP, soil-particles.

The raising of water in the stem, especially in tall trees, is a problem that has long exercised the minds of botanists. In some trees and shrubs, when the stem is cut off down to the soil, water oozes from the cut surface. This occurs most notably in spring, and the *bleeding* of vines from any wound is a well-known phenomenon. The quantity of liquid exuded may be very large—the birch or the maples may give off gallons in the course of a few weeks. Sometimes it is exuded under considerable pressure, which may be measured by a suitable pressure-gauge. The pressure is usually low, and a force of two atmospheres is exceptional. At two atmospheres the water would be raised by this **root pressure** to a height of only about seventy feet, and many trees are much higher. Moreover bleeding ceases, and with it root pressure, in the summer, so that at the season of the year when most water is required by the leaves there is no force acting from below to cause its ascent. The modern view is that the necessary force is applied from above by a pull or suction of the transpiring leaves. As water evaporates from the leaf-cells they suck in further supplies from below, just as the root-hair sucks in water from the soil. The suction force which is available in the cells of the leaf is fully capable of sustaining the column of water in the highest trees, and of moving it upwards against the friction of the wood. What seems strange is that the leaf should be capable of acting as a suction pump at such great heights, for the ordinary suction pump cannot draw water from a well more than thirty-two feet deep—the height of a water column which can be supported by atmospheric pressure. The explanation is that water suspended in the finer channels of the wood-

vessels, and thoroughly wetting their walls, behaves more like a string or rope than a liquid: such a column of water is exceedingly difficult to break. It is not supported by atmospheric pressure from below, but hangs, like a cord, from the leaf-cells above. This ingenious theory is confirmed by a great deal of experimental evidence and it seems to fit the facts well. It is of interest that the leaf-cells exert their greatest suction force when they are wilting, so that, as their necessity for water grows, so does their power of drawing it up the stem.

It has also been suggested that the living cells of the stem exercise a pumping action, but this has never been proved. Long tracts of stem may be killed by steam or poison, and through them water may be transmitted to the leaves above: indeed, a leafy shoot can draw up water through a long glass tube. This seems to show that, as regards water transport, the stem acts as a non-living conduit and that the motive power acts from above.

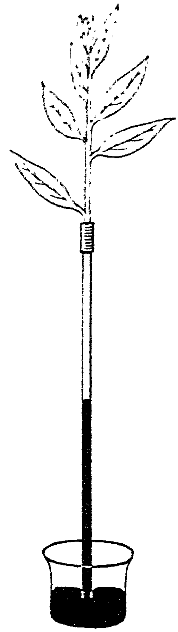

FIG. 427. LEAF-SUCTION

A leafy shoot is attached to a glass tube full of water which dips in mercury. As the shoot transpires the suction developed draws the mercury up the tube.

TRANSPIRATION

Despite its cuticle and its adjustable stomata, the leaf normally gives off water to the air. The drier the air, the hotter the sun, the more violent the wind, the more water is lost. When the leaf can absorb most light, and through wide-open stomata most efficiently supply itself with carbon dioxide, when, in fact, it can assimilate most vigorously, it automatically loses most water. Stephen Hales (1677–1761), the first man to apply exact measurement to experimental biology, estimated that on a warm summer's day a good-sized sunflower lost a pint of water, and a cabbage plant with half the leaf surface rather more. A forest tree may transpire fifty to one hundred gallons in the day. A beech wood of an acre in extent transpires over two thousand tons in the season of foliage. We may look on the matter from another angle. During its life from seedling to maturity an annual sunflower gives off as much as sixty pounds of water, more than ten times its final weight. An acre of sunflowers may send back to the atmosphere in five months ten of the thirty inches of rain falling on that area in the whole year.

When the soil is moist and rain frequent, the soft-leaved plants of

our gardens, meadows, and woods—sunflower, grass, and beech tree —can easily supply themselves with sufficient water to make good these huge losses. But when there is no rain for some weeks and the air is hot and dry, the supply from the soil begins to fall behind the demands of the plants, and we find the leaves drooping and wilting. Often they recover overnight, for, to begin with, the difficulty lies chiefly in the increasing slowness with which water passes through the drying soil. Later, unless the plants are watered, they wilt permanently. Against such dangers the soft-leaved plant is protected solely by its cuticle and by closing its stomata. It has been found that in drought some plants curtail the daily opening of the stomata to an ever shorter period in the morning, while others introduce a midday closure lasting longer and longer as drought endures. This does not afford certain protection in severe drought, as we may see by the wilting of plants in garden and hedgerow. Even with closed stomata so much evaporation goes on through the rather thin cuticle as to cause a serious drain on the water balance. Indeed such plants are fitted to thrive only when the water-supply is well maintained.

The commonest way of increasing drought-resistance is by alteration of the leaf structure. If a beech leaf from an exposed hedge is compared with one from a shady wood it will be found to be smaller, and to have a much denser network of veins. Now the veins are the water-grid of the leaf, and the more numerous they are the better will be its water-supply. The plant can resist drought by improving the anatomy of its supply system. Such leaves, too, are rather leathery and glossy, with a thicker cuticle. The best development of this line of protection is seen in the leathery leaves of the semi-arid Mediterranean *garigue*, and the Californian *chaparral*, where hot rainless summers impose a severe test. The thick cuticle of the leaves practically stops transpiration, so that, when in drought the stomata close, the loss of water is reduced to negligible quantities. We have already mentioned how the stomata themselves are protected in various ways from the drying influence of air and sun.

Many plants of dry situations are characterized by very small leaves; the heaths are a good example. It has been generally supposed that the small leaf surface acts by reducing transpiration. But the leaves, though small, are numerous, and it is doubtful if any great economy is effected thus. The small leaf, however, is especially well supplied with water, for every part of it is close to the midrib, and this may explain the success of these plants in dry situations. Some plants dispense with leaves altogether, and the stem takes over the work of assimilation. The broom has leaves of small area compared with that of the stem. The advantage gained here may lie in the smaller exposure to the heat of the sun of the erect switch-like stem. The blue gums of Australia

hang their leaves vertically, edge on to the midday sun, and so avoid its hottest rays. In many acacias the tender, feathered leaves are replaced by leathery, flattened leaf-stalks. In our own butcher's-broom the leaf-like organs are really flattened stems, as may be seen from the fact that the flowers and berries spring from their surface. These may be examples of an evolutionary tendency to produce a new organ of different origin more easily than to alter one already there, an exception to the general rule.

A curious fact may be noted here. Temperate evergreen trees have usually leathery leaves with thick cuticles like those of the dry summer forests. The leaf of our holly resembles that of the Mediterranean holm oak. Ivy, aucuba, rhododendron, cherry laurel, arbutus, are other examples. One reason for this may be that the leathery leaf is mechanically strong, and well able to resist winter storms. Another is that winter has its dangers of drought as well as of cold. White of Selborne noted that, in the great frost of 1768, the evergreens most damaged were not those in cold northern aspects, but those exposed to the sun. Even on a day of hard frost the sun may be warm enough to cause quite active transpiration, and that when a frozen soil prevents water-supply. A conifer after a cold spell may have its foliage browned on one side, and that the sunny one. We say that it is 'frosted,' but it is really burned up. Plants, of course, are killed by frost: the dahlias and scarlet runners go at its first touch, but evergreen plants are usually very hardy in this respect: their leathery green leaves do not protect them against cold, but against wind and evaporation.

FIG. 428. *Opuntia*, THE PRICKLY PEAR, A SUCCULENT PLANT OF THE AMERICAN SEMI-DESERTS (CACTACEAE)

The water problem may be attacked in other ways. The plant may provide itself with a store of water. The best examples are the *Cacti*, with their huge swollen stems, flattened, rounded, or ribbed. An apple leaf wilts with a loss of 1 per cent of its water content, and could with safety lose very little more. A cactus may lose over 50 per cent of its store and survive. The water content of one of these great tree-cactuses may vary by ten gallons in the course of a year. Many other plants have less conspicuous water-stores. In *Tradescantia*, the spider flower, commonly grown in our greenhouses, the cells of the epidermis are thicker than all the green tissue of the leaf together, and act as water-stores. The rubber fig, another common greenhouse plant, has also an epidermal store. The fat-leaved stonecrops and the

ice plants are familiar, the former perfectly at home on the tops of dry walls, the latter now acclimatized in many places on the Cornish cliffs. The houseleeks thrive in a minimum of soil, living between the tiles or slates of the roof. In drought all these draw on an unusually large internal water reserve.

Very curious are the many succulent plants of the seashore, e.g. sea-rocket, sea-feverfew, saltwort, and sand-spurrey. The sand they live in is dry on the surface only, and always wet a little way down. Some of them, such as the sea-feverfew and the scurvy-grass, prefer damp rock crevices. These are no true drought-resisters: indeed, deprived of water, they wilt unusually easily. Their succulence is due to some peculiarity of their chemistry, induced perhaps originally by the influence of the salt in the soil. It is something different from the succulence of the desert plant and does not help the plant in the same way.

Root Systems

In yet another way may the plant secure itself against a dry world. It may produce a specially effective absorbing root system. This method of defence, like the best defence in war, is an attack. The finest examples are the plants of the American prairies, where long summer droughts are prevalent. Prairie soil is deep, often ten to twenty feet, sometimes as much as thirty or forty. We may compare these figures with the two to three feet of soil, which is all that overlies the subsoil or rock in our islands. In such deep soils water may be available at great depths long after the sun has reduced the surface to dust. The prairie plants form root systems which run down six to twelve feet, and, in extreme cases, as far as twenty. Most of the fine absorbing rootlets arise far below the surface, so that the low-lying moisture is efficiently exploited.

An interesting case has been described from Pusa in India, where, in similarly deep soils, fruit trees—mango, custard-apple and peach—send down roots to a depth of twenty feet. The fine soil dries out lower and lower in the summer, and is waterlogged to the surface in the rainy season. In the dry season fine absorbing roots are formed, and function, at great depth. These perish in the rains, from lack of air in the waterlogged soil, and the new absorbing roots are formed even above the surface of the soil. Roots penetrating to the great depth of thirty or forty feet have been described for some plants living in deserts, such as acacias, the root systems of which were excavated when the Suez Canal was dug. But these are exceptional, for they are useful only when deep-lying veins of water are available. The true desert plant usually has only a moderate

root system and is protected by leathery leaves or by leaf-fall in the driest weather.

Finally, the plant may resist drought by fleeing it. The bulbous plants of the African karoos or of Palestine rest in the dry season, and spring to life in the rain. Grasses die down and persist as underground rhizomes. A host of annuals have a brief life when moisture is available, and persist through the drought only in the form of their seeds. The same thing may be observed in our sand-dunes, where mouse-ear chickweed and forget-me-not spring up and flower in spring, ripen their seeds in early summer, and then disappear.

The flowering plant has conquered the land surface. It has the means of absorbing water and conducting it to great heights. It has solved the problem of spreading an absorbing surface in the air without undue water loss. It has solved the problem of sexual reproduction without the necessity of water. In countries such as ours it may be said to lead a safe and comfortable existence. But it has set out to conquer the dry places of the earth, and in doing so has refined on its methods of coping with the problem of supply and loss. The semi-arid regions have yielded to the advance, and only the extreme desert is sparingly populated or even barren.

CHAPTER XV

THE LIFE OF THE PLANT: (2) MOVEMENT, GROWTH, DEVELOPMENT

Movements in response to gravity—Phototropism—Response to other stimuli—Characteristics of Plant growth—The life-history of the Plant.

MOVEMENTS IN RESPONSE TO GRAVITY

WHEN a seed germinates underground the root grows downwards and the young shoot grows up. If the seed happens to lie upside down, the root and shoot curve over till they find their proper direction. This curving movement is brought about as a response to an external stimulus—the influence of gravity. This movement is called **geotropism.** Its nature was first demonstrated by Thomas Andrew Knight, one of the eighteenth-century amateurs of science who added so much to our knowledge. He set seedlings spinning on a vertical wheel which was worked by a waterfall in his garden. The seedlings were acted on by gravity equally on all sides and by centrifugal force outwards. The roots grew towards the perimeter, the shoots towards the centre. When the wheel was set horizontally, gravity and centrifugal force acted, the one outwards, the other downwards, and the seedlings took up intermediate directions.

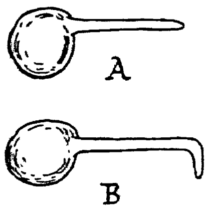

FIG. 429. GEOTROPISM OF ROOTS

A, a pea seedling laid on its side. B, the same seedling after twenty-four hours; the tip has bent vertically downwards.

How does the root perceive gravity, and how does it respond? It has no special sense-organs, but in the cells of its tip are numbers of starch grains which rest on the protoplasm of the lower walls of the cells. Lay the root on its side and the grains fall over to the side walls. There is good reason to believe that the root is only in a position of equilibrium when the weight of the grains bears on the lower walls—that is, those towards the tip. If they rest on another wall, the root changes its position till they lie once more at the bottom of the cell. Such is the rudimentary sense-organ with which the root perceives the external stimulus of gravity. And yet for the plant it is an advanced structure. For the perception of many stimuli we can find no specialized organs at all.

The root responds by moving, bending downwards. No special organs of movement are present, no contractile tissue. The movement is brought about by a change in the mode of growth. Instead of all sides of the root growing at an equal rate, one side grows faster. The movement is as slow—or as fast—as growth. After half an hour it is just visible to the naked eye; a day is required to bring it to completion. If I flex my arm I can straighten it again: but the growth-movement of the plant is irreversible. If the position of the root is once more altered, an entirely new curvature, made nearer the growing tip, brings about a fresh orientation.

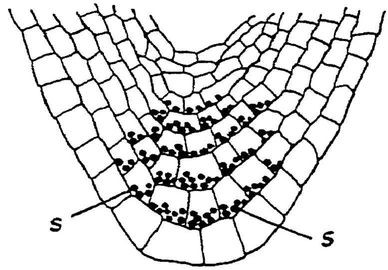

FIG. 430. STATOLITHS IN ROOT-TIP

Section through a root-tip showing the starch grains at S lying on the lower walls of the cells. These grains are called *statoliths*.

The influence of gravity on the plant is widespread, and often very subtle. Side roots grow out at an angle to the main root, and side branches at an angle to the main stem. This more or less horizontal direction is determined partly by gravity, and partly by internal influences, of which the action of the main axis is most important. If the tip of the main root or stem is removed, a side root or branch grows down or up to take its place, and now shows the effect of gravity unimpeded. We may often see this in firs or spruces which have lost their leader. Runners, such as those of the strawberry and creeping buttercup, and rhizomes, like that of the wood-anemone, owe their horizontal direction to gravity acting in more than one way, along with internal influences in the shoot. The twining of a hop plant or honeysuckle is induced and kept going by gravity. An organ may even alter the mode of reaction at different periods of its history. The bud of a daffodil is erect, the flower horizontal. The bud of a poppy hangs down, the flower is erect. All these positions and the movements which lead to them are directed by gravity, though light plays some part.

PHOTOTROPISM

An external influence which ranks in importance with gravity is light. Stems bend towards the light, roots may bend away from it, leaves arrange themselves so that the light falls vertically on their blades. It is not the direction of the light which causes the plant to move, but its different intensity on the two sides. In a rough way

we might say that the dark side of a plant tends to grow faster than the light side, so that the plant bends to the light. There are no special organs of light-perception. Yet it is the tip of a stem which is most sensitive, although the growth-movement occurs some distance further back. The young, white, first leaves of an oat or wheat plant are extremely sensitive to one-sided illumination and make a big bend in a few hours. If the tip be darkened by a little hood of tin-foil the leaf remains straight. Here, then, is some process of conduction of the stimulus, or rather of the **excitation** produced by the stimulus in the plant. Yet the plant has no nervous system whatever. It has been clearly shown that what is conducted is some chemical formed in the tip. This 'growth stuff,' as it has been called, passes downward and increases the rate of growth. Under this influence of one-sided illumination more of the growth stuff passes over the darker side which therefore grows faster, so that the leaf (or stem) bends towards the light. The same process of conduction is shown in leaves, for it is the leaf-blade of a *Tropaeolum*, for example, which perceives the stimulus, and the leaf-stalk which bends.

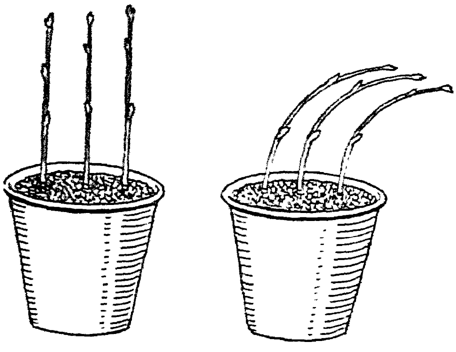
A B

FIG. 431. PHOTOTROPISM OF SEEDLINGS
A, vetch seedlings grown in dark. B, the same seedlings after twenty-four hours' exposure to light from the right.

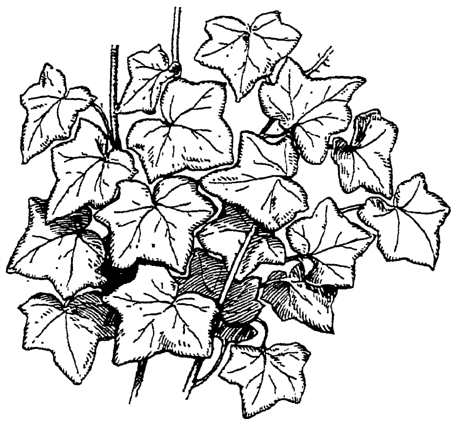

FIG. 432. LEAF MOSAIC OF IVY

The arrangement of leaves is exquisitely adjusted by response to light-stimulus. The sun moves round in the sky and the leaf cannot follow it day after day; when it is full-grown it cannot move any more. So we find that leaves take up a fixed position, and that this is related

to the direction from which most diffuse light falls on them. The leaves of ivy growing up a wall lie parallel to the wall's surface; those on the top of the wall lie horizontal, freely exposed to the sky. If we examine the mass of foliage more closely we find that there is nothing random in its arrangement. Leaf does not overlap leaf: rather each is fitted into the spaces left by its neighbours, so that the whole available area is completely occupied, and yet without mutual shading. The same thing may be seen in a garden nasturtium or in a Virginia creeper. In the horizontal branch of a maple we may see how small leaves fit into the spaces of large ones, how here a stalk is twisted to bring its blade into position, and there a long stalk is twisted up and occupies some vacant place. This mutual arrangement has been graphically termed **leaf mosaic.** In it we find the factor, light, which is the chief requirement of the leaf, itself directing the movements the leaf makes in coming to occupy the most satisfactory position.

Response to other Stimuli

The plant is sensitive also to such other influences as those of touch, shock, heat, and air. Sense of smell and taste we must deny it, but many plants respond to chemical influences. The tentacles of the sundew leaf bend over when touched by proteins or ammonium salts; the hyphae of a fungus grow towards food substances, and away from many poisons. The sperms of moss and fern swim towards sugars and acids; many bacteria swim towards oxygen.

Some species of *Mimosa* with beautiful compound leaves show, as every one knows, remarkable irritability. They are deservedly called **sensitive plants.** The pairs of leaflets fold their upper-surfaces together when touched; the message travels to other leaflets on adjacent pinnae of the compound leaf; then, as we continue teasing the plant, the pinnae narrow the angles between them and droop down; eventually the whole leaf-stalk moves on its jointed base and hangs down. If the stem of the plant be shaken violently there is an almost violent answer-back. By and by the parts recover their original positions. Similar movements take place naturally and slowly before nightfall, when the leaves close up and sink, and at daybreak, when they expand and rise. Botanists explain the movements as due to changes in the turgor of the cells at the base of the leaf-stalk and the parts of the leaf. Thus,

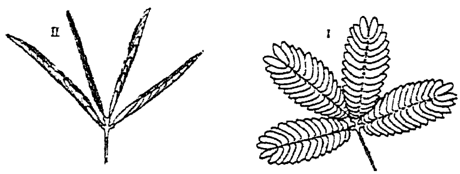

FIG. 433. *Mimosa pudica*, THE SENSITIVE PLANT

I, expanded leaf. II, leaf closed after stimulation.

when water passes out from cells on the lower side of the hinge into the adjacent intercellular spaces, the hinge must be depressed. But the more difficult problem has always been: How is the stimulus conveyed? If a terminal pair of leaflets be stimulated by the warmth of an extinguished match, the stimulus travels stemwards, from pinnule to pinnule, and eventually the leaf as a whole will droop. Or by wounding the sensitive under-surface of the hinge at the base of the leaf-stalk, we can start a stimulus which will travel outwards to pinnae and to pinnules. And the stimulus may travel from one leaf to another by way of the shoot—and very quickly too. It looks as if the plant had a nervous system, but it is better to restrict the word 'nerve' to the definite meaning it has in animal physiology. Till recently it has been held by botanists that waves of pressure pass through long, thin-walled, sap-filled tubes in the sensitive plant, just as a message might pass between two men holding the ends of a long rubber tube full of water. But the beautiful experiments of Ricca, an Italian investigator, have thrown a new and unexpected light on the problem. Ricca explains the distant conduction of stimuli as due to the transference of a hormone in the transpiration current in the wood of the stem. Mr. R. Snow has corroborated this interesting conclusion, and has told us something about the hormone—for instance, that it may be rendered inactive by dilution, but is not injured by drying. Mr. Snow believes that it is necessary to make special hypotheses to explain the transmission of stimuli in leaves, and also what he calls 'high-speed' conduction. But perhaps it will turn out that the hormone theory is sufficient.

Response to touch is shown by the tendrils of climbing plants. These organs may be parts of leaves, as in the vetches, or of branches, as in the vine. The tips circle slowly as if in search of support. If a tendril touches a solid object the contact causes the side away from the point of contact to grow rapidly, and so commence an encircling movement. Later the basal part of the tendril coils into a corkscrew, pulling the plant up to its support, and acting as a spring against the strain imposed by wind or passing animals. The tendril discriminates between liquids and solids. It is unaffected by the heaviest rain, but responds to the lightest contact of a fragment of thread.

In all these movements some external stimulus, often quite small in amount, starts off a train of reaction which leads to a movement in a direction dictated by the stimulus. Such directed movements are called **tropisms.** Movements of quite a different kind are exhibited in the opening and closing of flowers, and the folding-up of leaves at night. Flowers usually respond to changes in temperature. The crocus and tulip, opening in the sun, respond to heat and not to light. They open as rapidly in a dark, warm room. They close again in the cold,

though they also close partially after some time in a high temperature. Other flowers that react in this way are the water-lily, the dandelion, the flax, the scarlet pimpernel. Some, as the marigold, respond also to change from darkness to light. Many flowers behave in a more complex fashion in that they have a tendency to open and close at definite hours, independently of external conditions. Often this inherent rhythm is combined with, or controlled by, the external change. It is well known that flowers open and close at different hours, and some — like the sweet-scented stock and the night-flowering cactus — open at night. Linnaeus constructed a floral clock to tell the hours by the opening and closing of a number of different flowers —an unreliable timepiece in our climate.

The folding of leaves at night and their opening by day is shown well by the wood-sorrel and clover. Leaves usually respond to changes of light rather than of temperature. Usually they, too, have an inherent rhythm, which may entirely control the periods of movement. The folding of the leaf at night probably guards it against overcooling and deposition of dew. The opening of the flower is of course related to pollination. Night-opening flowers are pollinated by night-flying moths. When the flower closes, its pollen is protected from rain, and pollen is often very easily damaged by pure water. In all these the external stimulus may set the movement going, but it does not *direct* it.

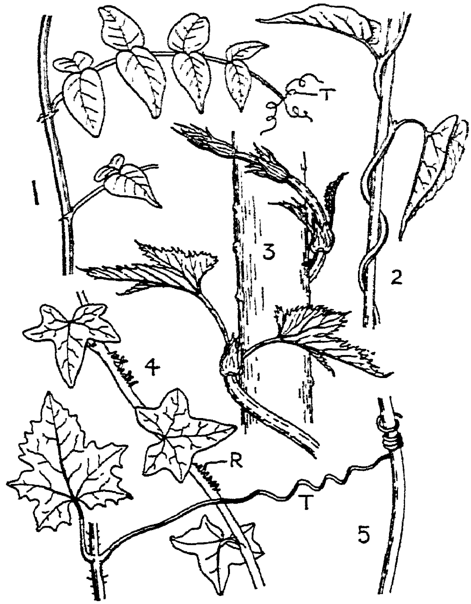

FIG. 434. DIFFERENT WAYS OF CLIMBING AMONG PLANTS

1, vetch with leaflet tendrils at T. 2, stem of bindweed twining counter-clockwise. 3, stem of hop twining clockwise. 4, ivy with adventitious climbing roots at R. 5, bryony with tendril at T.

We could multiply examples of plant movement, but enough has been said to indicate their variety and the many ways in which they are used. They show the plant reacting to the influence of the outer world in a hundred different ways, yet response by movement by no

means exhausts the plant's exhibition of sensitiveness. The leaf of the beech takes on different structures to meet the different conditions of sun and shade. The plant growing in the dark remains white and stretches its stem to an unnatural length: it may by such means attain the light it requires. The weight of the branch induces the development of special strengthening tissue at its junction with the stem. The amphibious persicary forms floating leaves, or land leaves, according to its station. The alpine specimen of hawkweed becomes dwarfed and hairy, and flaunts a more brilliant flower than the lowland plant. The summer wood has smaller vessels than that formed in spring. We might multiply examples, but these serve to show how sensitive the plant is to its environment. In a much less noticeable way than the animal it keeps in touch with circumstance, and orders its life to meet the demands of a variable world. Indeed, it is only on these conditions that the plant, or any organism, can advance or even survive.

Characteristics of Plant Growth

A major feature of the organization of the flowering plant is its capacity for adding to itself over long periods of time. Even the largest animals reach maturity in a few years and then grow no more in size. But a forest tree may be the best part of a century in reaching its climacteric, and it may still be adding new parts to itself for another millennium. Of course, growth continued for so long cannot be of the same kind as that of the animal, which consists, in essence, of increase in size of organs already formed in the foetal stage. The trunk of a tree goes on increasing in girth, more slowly with advancing years, but even the tree trunk does not increase indefinitely in height. The main feature of the plant's growth is the power of continually forming new shoots and roots by branching, and of continually renewing outworn parts, as in the production of new leaves and flowers.

The plant grows at all its tips. A branch does not increase in length over its whole extent. This would be impossible, for it consists, except at the apex, of inextensible wood. The tip of every branch, whether of root or shoot, is occupied by a little cap of tissue consisting of nearly undifferentiated cells endowed with the capacity of unlimited division. So behind it new cells are continuously formed, while growth is active. These new cells, as they are produced, stretch and so grow in length, and this extension is restricted to a distance usually of only a few inches behind the tip. As the cells attain their full size they undergo the changes which bring them into their final form, as wood-vessels, fibres, sieve tubes, epidermal cells, and so on.

The growth of perennial plants, and especially of trees, takes place

rather differently. In a beech, for example, or a fir, the cells for the next season's growth are laid down inside the winter-resting buds. In spring all these cells expand together, or successively, and complete the growth in length for the season in a few days, or weeks. A new apical resting bud is then formed, and is ready to expand in the following spring. Some trees, however, continue growth, forming new tissues at the shoot apices, till late in the summer. The enormous shoots of a balsam poplar, sometimes attaining a length of six feet in a year, illustrate this mode. The hazel shows both methods, for shoots springing from the base of the tree may grow all summer, while those of the crown behave like beech shoots.

GROWTH OF THE ROOT.—The root is peculiar in having a very short zone of extension, only about a quarter of an inch long, very close behind the tip. This is related to the conditions of its existence. The root-tip must be forced through the soil, and this is best effected if the force available in its extension is applied just behind the tip. When an amateur tries to drive home a long wire nail he often buckles it, while with a short nail he is more successful. The difference is that, in the first case, the force is applied too far back. In the same way the root would buckle if the stretching zone were too long. A second reason is that the root produces root-hairs not far behind the tip. If these were in the zone of extension they would, as the root stretched, be torn from the particles of soil to which they glue themselves. The difference between the growth of root and stem is only one of degree: in both the zone of extension is restricted: in the root it is specialized in relation to the conditions of growth in the soil.

BRANCHING.—Associated with the capacity for continued growth in height is the capacity for branching. Mere growth in length would be a very uneconomic proceeding; it would exploit available space very badly. With the production of branches the plant's power of spreading leaves to best advantage in the air, and of using the soil efficiently, is enormously increased. Shoot branches are formed quite close to—within one-thirtieth of an inch of—the apex. They appear as small bulges of dividing cells. Each bulge increases somewhat in size and then becomes a growing tip on its own. Leaves also appear in the same position and in the same way. The bulge which is going to form a branch always arises just above the bulge that will be a leaf. So it comes that the bud which can become a branch always stands in the **axil** of a leaf. Not all such buds develop further, but all have the potentiality of a new shoot in them. A bud may rest for years and then spring into growth. The position of the bud in the leaf-axil means protection and favourable conditions of nourishment; for the food substances from the leaf stream past the bud on their way to the stem. This arrangement is a comparatively recent

one. It does not exist in the ferns, for example, in which the leaf-axils have no buds. It appears from its success to be very efficient, and in the flowering plants it is standardized.

Branching is never disorderly. The leaves are always arranged on some very definite plan. The simplest is shown in the grasses, where each leaf springs from the side of the stem opposite to that of the leaf below or above. In the maple or the nettle two leaves always arise opposite each other at the same level. Each pair stands at right angles to the pair above or below. The commonest arrangement is, however, a spiral, so that as we trace the stem upwards we find each successive leaf at a higher level, and shifted by a definite angle round the axis. The leaf-spirals vary in their pitch, and so in the angle between one leaf and the next, from species to species; in any one species there is usually a constant type. It will be clear that this orderly arrangement utilizes the available light much more fully than could a haphazard grouping, where leaves would be much more likely to overshade each other. In the mature shoot, however, the position of the leaf-blades may show little trace of the fundamental arrangement, for the mature position is determined by the light actually falling on the shoot. A maple bears leaves in crossed pairs, but a horizontal branch has all the blades in one plane. An orderly arrangement provides the groundwork on which takes place the business of adjustment to the conditions in which the individual shoot finds itself. The orderly arrangement is probably determined by the space conditions at the growing-point. More room for development, and more satisfactory nourishment, are possible for the little primordial bulges when they are regularly spaced, than would be the case did they grow out haphazard.

The position of branches is, then, dependent on the position of leaves, but is also subject to many later adjustments. Many buds fail to grow and the branches corresponding to them are missing. Branches to the outside of a tree are favoured by the better illumination. Many of those inside cease their development early and are cast off. Just as the husbandman prunes his orchard to get the trees into good shape, so the tree prunes itself in Nature. Otherwise it would bear a thicket instead of a crown. The result of original disposition and such subsequent adjustment leads to a branch-work highly characteristic in different trees. It is a fascinating pastime in winter to study the skeleton of the tree's branch-work, identify the species from its form, and trace the individual characters involved.

The branching of roots differs from that of shoots in many ways. The root primordium takes its origin *inside* the parent root, and not on the surface. It bursts its way to the outside through the parent tissues. In this way it is, from the start, in intimate connection

with the conducting wood which it is to supply. Many plants form roots on the stem—**adventitious roots** they are called—and these, too, arise inside the rind. They may be seen bursting out from a willow twig placed in water. The main part of the root system of monocotyledons is composed of such adventitious roots arising from the base of the stem. Side roots do not arise in the axils of leaves, but they are none the less orderly. They generally arise in a number of rows arranged vertically along the side of the parent root. A beetroot shows two and a carrot four rows of small fibrous absorbing roots. The rows correspond in number and position to the bundles of wood in the parent root with which the branch roots make connection. The final form of a root system is nearly as varied as that of the crown of a tree. The main or **tap root** may predominate, going deep into the soil, or the side roots may overtake and surpass the main root, or the system, as in the cereals, may be mainly adventitious.

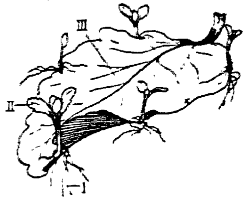

FIG. 435. LEAF OF *Bryophyllum*
The leaf when separated from the plant forms buds in the notches. I, roots of young plant; II, young plant; III, leaf.

REGENERATION IN PLANTS: VEGETATIVE PROPAGATION.—A third feature of plant growth is the extraordinary power of regeneration which allows us to take a cutting, root it in the soil, and make a new plant of it. The cutting need not be a shoot, though that is commonest — we think of carnations, lavender, violas, snapdragons, and dozens of other plants propagated in this way. In some plants, leaves produce buds which root and give new plants, for example *Begonia* and *Bryophyllum*. In others, portions of the roots can form buds; of these the seakale, the Californian poppy, and *Bouvardia* are examples. This power of regeneration depends on three things—the capacity for forming new parts, the capacity for producing new growths from a cut surface, and the lack of integration in the higher plant.

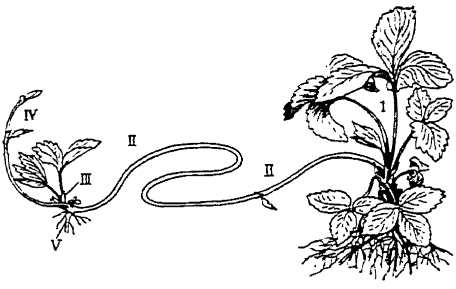

FIG. 436. STRAWBERRY WITH RUNNER
I, strawberry plant; II, runner or stolon; III, young plant; IV, runner from young plant; V, adventitious roots.

The leaves and branches draw water and salts from the parent trunk and supply it with food, but this nutritional relationship is almost all that binds a branch to a tree. It is not a member of the body

in the same sense that an eye or an ear is of ours. The branch plays its part in the general life, but the body of the plant is much less closely knit than that of the animal; the parts are much more independent. The tree does not feel the loss of a branch, and the branch parted from the tree may start life on its own. This is a regular and natural proceeding in many herbaceous perennials. The strawberry produces a runner or **stolon**—a special type of branch; the runner roots at the tip and forms a new rosette; its base rots away and two plants, once organically connected, grow where one grew before. The rhizome of an anemone or Solomon's seal branches underground; the older part dies off; the new branches become independent plants. Between this and the artificial severance of a shoot to form a cutting there is no fundamental difference.

The cutting forms adventitious roots, as we have said, and this differs in no way from the normal formation of such roots by a cereal. It is usually stimulated by the severance of the shoot from the parent, though some plants root more readily when they are layered. Here there are very wide individual differences. Many plants are difficult to strike, some impossible. We know very little about the factors which cause a root to form on a stem; but it is clear that all the conditions of water-supply and food-transfer are altered when the shoot is removed from its parent.

Sometimes roots are formed from a swollen tissue or **callus** which grows actually on the cut surface. From the callus, too, buds giving rise to new shoots may spring. If a tomato is decapitated the dormant buds in the axils of the leaves will start into growth and give new shoots. Here we have a variation of normal growth. But if these buds are broken off and prevented from growing, then, from the callus which forms on the top of the stump, new shoots arise. This is true regeneration and it is something new. The plant's power of renewing its growth, then, is not confined to one place, but is very varied. The clever gardener knows how to take advantage of the peculiarities of different species so as to propagate plants rapidly on these lines.

The Life-history of the Plant

The germination of a seed takes place in diverse ways. The cotyledons may remain within the seed-coat, acting merely as food-stores, as in the pea or broad bean. Or they may leave the seed-coat and come above ground to function as the first assimilating leaves, as in the sunflower. The single cotyledon of an onion functions as a foliage-leaf, and also serves to draw the food reserves from the endosperm. In general the cotyledons are unlike the foliage-leaves. Even

when they become green they are smaller and simpler in shape. The first foliage leaves, too, are usually smaller and simpler than those which follow. Thus a process of development and orderly succession of stages of diverse nature leads from the single fertilized egg-cell to the young plant complete with roots, stem, and leaves.

The subsequent history varies with the type of plant. Annuals

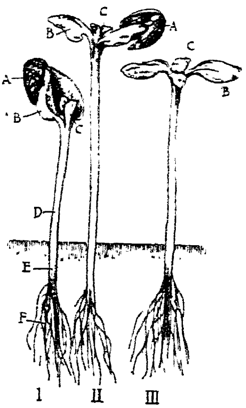

FIG. 437. GERMINATION OF SUNFLOWER

A, fruit-wall; B, cotyledons which come above ground and become green; C, apical bud; D, hypocotyl or seedling stem; E, root; F, side roots.

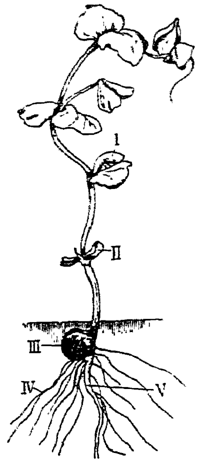

FIG. 438. GERMINATION OF PEA

I and II, leaves; III, cotyledons which remain underground; IV, side roots; V, main root.

show little variety. The young plant grows large and branches, and finally flowers, fruits, and dies away, its story complete within the compass of a season. The biennial has a more varied story. A foxglove in its first year forms only a rosette of leaves. In the second year, with this established foliage for a start, it produces more leaves and also the massive spike of flowers; with the ripening of the seed it, too, dies. The carrot also produces a rosette of leaves in its first year, and its main root thickens and stores food. The store enables it to throw up a flowering head of size disproportionate to its foliage. Turnip and beet differ only in this, that their thickened 'root' is part root and part stem. The process of development of the biennial is thus more complex than that of the annual; the longer life is accompanied by a greater difference between the vegetative and the

reproductive stages of the life-history. A longer preparation leads to a great yield of seed.

In the perennials we find the greatest variety. The herbaceous perennials of our garden usually flower in their second year. Although the flowering stem dies down, the plant persists underground as a **crown** with roots attached to it (lily of the valley), **stock** (primrose), **rhizome** (Solomon's seal), or **tuber** (sunflower). Year after year the process is repeated. Some perennials seem to go on almost indefinitely, like the Michaelmas daisy; others have a shorter life, like the lupine. Perennation is often accompanied by vegetative propagation. New buds are formed underground, rhizomes branch, runners establish themselves. All these processes lead to increased numbers, and also to a slow spread which often occupies considerable areas. Such perennials of our woodlands as the wood-anemone and dog's-mercury are good examples of this.

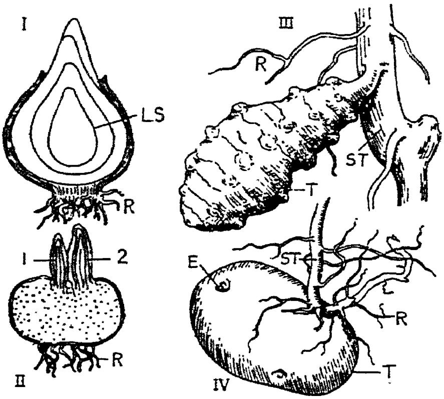

FIG. 439. UNDERGROUND PERENNATING ORGANS

I, section through tulip bulb: LS, fleshy scales; R, roots. II, section through crocus corm: 1 and 2, buds; R, roots. III, artichoke: ST, stem; R, roots; T, tuber. IV, potato: ST, stem; R, roots; T, tuber; E, bud or 'eye.'

The bulbous plants are highly specialized perennials. The **bulb** of a snowdrop consists of three white, fleshy scales, rich in stored carbohydrates. These are really the bases of the two foliage-leaves of the previous year and of the white, sheathing leaf which surrounded them. They are covered on the outside by the withered remains of still earlier leaves. Within stand the flower-bud and the young leaves for next spring. The whole is set on a very short disk-like stem. The stored food enables the flower to develop early in the year and to set its fruit while the weather is still too cold to allow of much assimilation taking place. Later the leaves manufacture food and pass it down to their bases, which swell and become the scales of next year's bulb. Meanwhile within them a new flower-bud and new leaves are being formed, and are well advanced when the bulb goes into its summer rest. New bulbs are produced as offsets from buds arising on the short stem in the axils of the leaves. Thus the bulb goes on from year to year, sending up annually flower and foliage, multiplying, and itself persisting, yet ever renewed, underground.

Other bulbs grow in other ways. The tulip forms an entirely new bulb every year, and its scales have no connection with the foliage-leaves; they are formed for storage alone. *Crocus*, *Colchicum*, and *Montbretia* perennate by corms, easily distinguished from bulbs because they are solid and not built up of scales. The corm is, in fact, a thickened stem bearing at the side, or on the top, a bud which will grow into flowers and foliage, and the base of which will thicken to form next year's corm. Extra buds produce new corms, and again perennation is accompanied by propagation.

The life of tree or shrub—the tree is just an overgrown shrub with a main stem—appears more monotonous; but the course of its life is varied. The seedling grows into the sapling, with its slender stem bearing branches almost to ground-level. The sapling reaches its trunk to adult height, and the crown of the mature tree begins to form. At eighty years a tree like the beech is fully formed in its figure; thereafter it grows in height very little. For a like space of time it lives with little outward change, and then decline sets in. The centre of the trunk may rot: fungi and bacteria of decay get a hold; the foliage becomes sparser year by year. Old age may last two centuries or more, till some storm brings down the decrepit ancient.

Woody plants do not die down in winter, but none the less they often show an annual periodicity of growth. In the rain forests of the tropics most trees are evergreen, though even here the appearance of uniformity is misleading, for the leaves are usually cast in batches and new buds open together. The same plan of leaf-shedding and renewal is shown by our own evergreens, holly, laurel, privet, and pine. In a climate with a cold winter the evergreen is protected by its hard and leathery leaves from damage by storm and too much loss of water. Though it retains its summer canopy of leaves it is forced by circumstance into a state of comparative rest. The same type of leaf protects the evergreen oaks and laurels and olives of semi-arid countries from the drought of summer when many other plants die down. Strange that the same sort of adaptation should be of use in conditions so diverse.

Both in climates with cold winters and in those with very hot summers many trees shed all their leaves periodically in the unfavourable season. In some parts of India and Java the teak trees stand bare in the hot months. With us leaves work hard all the summer, and they are in some measure worn out in autumn. So they begin to die, and they die in many cases very beautifully.

If they continued active they would be sources of weakness, for they would be using and losing water, which becomes less and less available as the winter draws near. Even if they obtained sufficient water, it might be apt to freeze in the delicate tissues, and then the

leaves would prove vulnerable points for the tree. So in the great majority of cases they fall.

Across the base of the leaf-stalk there grows a special separating layer of cells, differing from their neighbours in showing greater turgescence, denser protoplasm, more abundant starch, and thinner walls. Soon the walls of the cells in this layer become mucilaginous; the cells disintegrate along the plane of separation; the wind breaks off the leaf; and after this happens, or even before it, a layer of cork closes up the wound and makes a healing scar.

Apart from the wear and tear of the summer's industry, apart also from the great reduction of the available water-supply, there are waste-products which may become poisonous, and are also liable to clog the transporting tissues.

The fall of the leaves certainly helps to make the tree a singularly well-protected, quiescent organism in winter. As evergreens show, the autumnal fall of the leaf is not necessary, but in ordinary cases it is very profitable, even life-saving.

Along with the 'chlorophyll-greens' there are two 'chlorophyll-yellows,' belonging to another series of pigments (**carotins**) that are familiar in shrimps and prawns and in the bright colouring matter of carrots. When a leaf dies, a contribution to the coloration is made by the disintegration of the chlorophylls so that the carotins are left. Simple golden-yellows, as in elm trees and willows, have this origin.

There seems no doubt that some useful results of the breaking-down pass by the leaf-stalk into the branch, for it is characteristic of the dying leaves that they surrender to the parent tree all that they can, so that they enrich it in their death as they have enriched it in their life.

When the separating partition is formed, transport from the leaf has to stop; but the fallen leaves contain little but waste. Their wonderful colouring may be appropriately called 'beauty for ashes.'

We may use the term 'flower blue' as a translation of **anthocyanin,** to which is due all the more vivid colouring of the flaming crimson maples and purple cherry, besides brambles and roses in the undergrowth, and the Virginia creeper on the houses by the river-side.

Chemically considered, anthocyanin is a **glucoside,** that is to say, a combination of grape-sugar (glucose) with some aromatic substance. Naturally enough, it is found abundantly when there is a local accumulation of sugar, and this again is due to the lowering of the temperature in autumn.

It is difficult to believe that all this foliar gorgeousness, rivalling that of flowers, is of no use to the trees. Perhaps the anthocyanin serves as a screen, absorbing the rays that may be injurious to the ferments still at work in the moribund leaf. Perhaps it absorbs rays that increase the temperature of the leaf and stave off death a little while

longer. Perhaps, however, we are too keen to discover utilitarian justifications for beauty; it may be that the anthocyanins and the like have no great physiological significance, but merely represent a by-play in the leaf's graceful dying.

Why are some woods, like those of the St. Lawrence, so exceptionally beautiful in autumn?

It seems to be due to a happy combination of three factors—plenty of water, abundant sunshine, and yet a low temperature. These factors make the dying slow, giving time for the gradual disintegration of the greenish and yellowish pigments and an abundant formation of anthocyanins.

In shrubs and trees vegetative propagation is not common as in herbs. Trailing branches of shrubs may root; trees send up suckers, and the shoots from the stools of felled trees form coppices; some trees, as the elm, send up suckers from their roots. These are exceptions. The tree depends on its seed for reproduction. Some trees begin to fruit before they reach maturity: the birch flowers at ten years and the pine at fifteen. Others reproduce at a more mature age, the oak and beech at forty to eighty. Flowering in trees is usually periodic. A 'mast' year, in which enormous quantities of acorn, beech mast, or chestnut are produced, is succeeded by a series of years with little or no fruit. The same periodicity is known for the fruiting of apples, pears, and plums. Partly it is due to favourable seasons; the season which favours flowering being the previous one, for in trees, and many shrubs, the flower-buds are laid down a year in advance. More important, it is necessary for the tree to spend several years in laying up a store of food which shall suffice for the ripening of an enormous multitude of seeds. An extravagant development of this tendency is seen in the century plant, an agave, which grows for some ten years, produces an immense inflorescence, and dies exhausted. In South Europe, less favourable in climate than its native Mexico, the agave lives much longer before flowering and so has earned its English name.

CHAPTER XVI

THE PLANT AS A SOCIAL ORGANISM

The forest—Heath and moor—Grasslands—Other Plant societies.

IT does not need much knowledge of botany to recognize that plants live in societies. A **forest** is a society of trees as a **meadow** is a society of grasses. Such societies imprint their character on the landscape, and ordinary language recognizes their importance in the topography of the country-side. The word **heath** implies not only a barren and sandy soil, but also the dwarf shrubs which cover it. The word **pampas** means not only the rolling plains of South America, but also their waving grasses. So it is with **moor** and **fen,** with **dune** and **tundra.** Each different type of country has its appearance determined at least as much by the vegetation clothing it, as by its features of soil and surface relief. This is not so much because the different societies of plants consist of different species, but because, in each, some particular **growth-form** is dominant—herbs in meadow and pasture, dwarf shrubs in heath, trees in the forest. The dominant growth-form largely determines the conditions in which the associated plants must live, and so is responsible, not only for the general look of a society, but for the details of its composition. Let us illustrate the way in which such a society is built up and lives by the example of a forest community.

THE FOREST.—The forest most characteristic of Britain is the oak wood. Charles II hid in an oak tree; the arrow that killed Rufus glanced from an oak; Robin Hood's greenwood was the Sherwood Forest of oaks; and we may well believe that the Round Table was made of oak and was spread in the shade of the oaks of Somerset. We have really two species of oak native in this country, though they are very much alike in general appearance. The common oak (*Quercus Robur*) is most at home in damp and clayey soils, and is the tree of the forests of the Weald. The durmast oak (*Quercus sessiliflora*) builds forests on lighter and more sandy soils, as in the New Forest and Sherwood Forest. The oak wood is dominated by the oak, though there may be an admixture of maples, ash, hornbeam, beech, and other trees. In a mature forest the trees form a close canopy, so that, in summer, the light falling on the ground is very much limited, and smaller trees, shrubs, and herbs are at a serious disadvantage;

for in the shade they cannot find light enough for photosynthesis. They tend, too, to be drawn and straggly, and to have thin and delicate leaves. Small trees and shrubs are most abundant and vigorous in clearings and along the rides and edges of the wood. In such places we may find hazel, dogwood, hawthorn, blackthorn, willows, junipers, and wild roses. We can now recognize as partners in the forest community two distinct groups of plants, the dominant trees and the associated shrubs, each with its own growth-form and position in the society.

A third class is formed by the climbers, but these are not very important in our English woods; woodbine, ivy, and black bryony are the most prominent. A fourth group includes the epiphytes. Mosses and lichens may grow on the tree trunks. A pocket of soil in the crook of a branch may give foothold to an occasional polypody fern or a tuft of grass. But this group is much poorer with us than in the forests of the tropics. Finally we have the fifth group, which consists of the ground vegetation. Here we may find such herbs as wood-anemone, goldilocks, lesser celandine, red campion, dog-violet, wood-sorrel, sanicle, periwinkle, speedwell, dog's-mercury, stitchwort, woundwort, wild garlic, bluebell, sedge, bracken, and many others.

We see, then, that a forest is by no means a homogeneous community of trees. In it plants of the most diverse habit grow together. We may regard it as built up in layers, like a many-storied building —tree layer, shrub layer, ground vegetation, and, transgressing these horizontal boundaries, the scanty epiphytes and climbers.

How these different types of plants can live together is most obvious for the climbers, for the taller shrubs and trees are the prime condition of their successful life. A more intricate story is that of the ground vegetation. The species we have cited as examples do not grow uniformly distributed throughout the wood. Some are lovers of light —e.g. campion, stitchwort, bracken—and these grow in the clearings and along the margins. Others can withstand shade—e.g. bluebell, dog's-mercury, lesser celandine—and these grow more under the trees. How do these plants gain the light necessary for photosynthesis? For the most part they start work early in spring and work vigorously before the oak becomes leafy. Celandine and bluebell are well known as early flowers. It has been found that there is a close relationship between the date of appearance of the leaves and the depth of shade in which a plant grows. Dog's-mercury and lesser celandine send up their leaves in February, and grow in the deepest shade; bluebell and wood-anemone are a month later and occur only in better lit areas. The leaves of all these plants fade and wither early in summer, when they are no longer useful. The wood-sorrel, with leaves that last through the season, builds up most of its food-store in early days, and

in the summer shade assimilates just about enough to meet its losses in respiration.

In a sense, all these plants are protected by the shade of the oak, for the ranker vegetation of tall herbs and grasses, which require more light throughout the summer, is excluded, and the shade-dwellers are consequently freed from their competition. Thus the oak tree makes the conditions in which its peculiar associated flora lives, and, in absence of competing plants, the bluebell and anemone are free to form those continuous sheets of sky blue and starry white which are one of the most beautiful sights of the woods in spring.

The bluebell also exemplifies another mode of living together. On rather deep soil in some oak woods it grows in association with the bracken and the soft-grass in open woodland glades. It avoids competition with the bracken by its early growth. By the time the shady fronds of the fern are fully expanded its year's work of photosynthesis is done. The soft-grass survives, partly because its long narrow leaves and panicles can grow up between the bracken fronds, but more because it goes on growing very late in autumn and starts early in spring. We have thus three herbaceous plants utilizing the same space with mutual tolerance. But these three avoid competition below ground as well as above. The bluebell bulbs lie deeply buried, above them run the rhizomes of the bracken, and on the surface, in the loose litter and leaf-mould, roots the soft-grass. On shallow soils, which are also drier, the soft-grass is replaced by the hair-grass. This forms close, wiry tufts difficult for the bluebell to pierce, and a bad bed for the germination of its seeds. Partly for this reason, and partly because the shallow soil does not suit it, the bluebell is absent from this society. The nature of the society is here influenced by the conditions of the environment. Let us note again that shade cast by tall plants is an advantage to any which can by one means or another put up with that shade, for shade excludes many species and reduces competition.

A fine example of the dominating influence of the tree canopy is afforded by many of our oak woods which are grown on the 'coppice' system. In this the trees are felled at regular intervals, usually every twelve or twenty years. Young shoots spring from the stools and grow into saplings, which are of a size fit for fencing and other such uses when the time comes for them to be cut once more. There may be left a number of standard trees which are not coppiced—a favourite number was twelve to the acre. These standards take on a different form from trees grown in 'high forest,' that is, with all the trees allowed to grow to maturity. Such trees are tall and straight with few branches, and yield the best planks from their timber. The standards grow like trees in the open, widespread, with low and very large branches. They

yielded the 'knee-pieces' required in the building of ships, in the times when our navy was oaken. The needs of the navy determined the chief system of forestry of the oak woods. Though the last felling for the navy took place nearly a hundred years ago, coppicing is still practised, for it yields a supply of timber useful in estate work, while the coppice is favourable to the game birds. Now, when the wood is coppiced it is clear that the light conditions of the ground flora are suddenly improved. The newly illuminated ground is quickly invaded by the rank herbs and shrubs which previously grew on the edges of the wood. Brambles, hazel, hawthorn, roses, and other shrubs spring up; grasses, campions, foxglove, and woundwort spread. The previous flora of anemones, celandine, and dog's-mercury becomes scantier, smothered in the scrub. As the stool shoots of the oak get taller the reverse process sets in. The coarser growths have less and less light in summer when they need it, and they begin to go back; the woodland ground flora increases, and resumes its former importance. Thus, in a cycle of a dozen years, we see how the competition for light may entirely change the character of a flora.

Other types of forest may have an even denser shade than the oak. There is an old saying that 'Under beech and yow, nowt 'll grow.' This is true of a beech wood in summer, when the ground may be completely vacant but for an occasional bird's-nest orchis, a saprophyte which requires no light. Even the vernal flora is restricted, for the thick leaf-litter of the beech wood resists both the penetration of roots and the emergence of shoots. The beech wood is not coppiced, and is an example of high forest. This also tends to reduce the number of its companions, for light-loving plants are not periodically favoured. So we find that there are usually no other species of trees in the beech wood, and few shrubs. Sanicle and dog's-mercury occur in places where the canopy is thin. The shade of such a wood makes its own regeneration from self-sown seedlings difficult. Seed may sprout freely, but the light is too poor for the seedlings, even if they do escape the ravages of mice and rabbits. It is usually the spaces left by fallen trees that give the opportunity for seedlings to grow up. It is said that one animal helped the regeneration of oak and beech woods, viz. the pig, herds of which, in former days, were driven into the woods to eat the mast, trampled enough seed into the soil to give many seedlings, and, in trampling and rooting about, cultivated the soil and made it a much better seed-bed than the natural litter to which we have referred. It is therefore not surprising that the home of the wild swine should be the forest which they help to preserve.

In woods of fir and spruce—neither native in this country—the shade is often so deep as to exclude other plants entirely. The pine forest—of which there are still a few native remnants in the Highlands—casts

less shade; often, indeed, pine trees grow thinly scattered in the heather heaths in which the woods merge. The shrubs here include bilberry, cranberry, ling, juniper, birch, and mountain ash; and the ground flora includes hair-grass, cow-wheat, hard-fern, chickweed wintergreen, and *Goodyera*, an interesting little orchid of the northern woods. Pine, fir, and spruce have their shading effects very much magnified by a feature they have in common—their evergreenness. This means, of course, that there is no light phase in the pine wood in spring, and so we do not find the vernal flora so characteristic of the deciduous woods of the broad-leaved trees.

Forest once covered the greater part of our islands, beech in the extreme south, oak over all the midland region and even as far north as the Highland line, with pine beyond. The activities of man have reduced it to a fragment of its former area. Clearings were made for cultivation; great tracts were felled for timber. Charcoal was required in early days for iron-smelting. Fire and the axe cleared vast areas which were the home of savage animals and wild tribes. Not all the cleared areas were suitable for agriculture, and other types of vegetation invaded them and held them, partly with the aid of grazing animals. So in the south we have regions of upland pasture; in East Anglia there are heaths; in the north the heather moors and the peat moors. At low levels, where the soil is fertile, cultivation is the rule, much of the land being meadow, an artificial form of grassland.

HEATH AND MOOR.—Heath, moor, and upland pasture are distinguished by their soils and their characteristic plants. The **heath** is characteristically a community of dwarf shrubs on a light, dry soil. The heaths of sandy soils have, as their commonest shrub, the gorse, sometimes growing tall and straggly, sometimes nibbled into thickset bushes by sheep and rabbits. Broom, brambles, and juniper abound, with taller clumps of blackthorn, hawthorn, and buckthorn. Between the shrubs grow such grasses as hair-grass, bent-grass, and the fescues, and herbs like milkwort, cow-wheat, heath bedstraw, and speedwell.

The **heather moors** cover extensive tracts of upland in Scotland and Yorkshire, where they are economically important as grouse moors. Their thin, peaty soil, dry in summer, supports a vegetation in which the shrubby ling or heather is completely dominant. In England it is often accompanied by the beautiful summer-flowering Welsh gorse. Other shrubs are the crowberry, whortleberry, bilberry, petty whin, fine-leaved heath, and creeping willow. The soil under the shrubs is often bare or sparsely covered with lichens. In spaces where the heather is short or open, fescues, mat-grass, hair-grass, and bents form a turf diversified by milkwort, heath bedstraw, and hawkweed. On moors where grouse are preserved the heather is burnt

off periodically, for low-growing heather is best for the birds, and the berry-bearing shrubs get a better chance. After burning, it is interesting to see how the re-vegetation of the moor takes place. The first invader of the charred surface may be the reindeer moss (a lichen) (p. 1097), and it is followed by the fine-leaved heath and the bilberry. Heather seedlings spring up rapidly, but they do not grow much for a year or two, and some time elapses before heather is once more dominant. Heather shoots come up too from old roots.

The heather moor is rather a heath than a moor, for it has the characteristic dwarf-shrub vegetation and its soil is usually thin and poor. On upland plateaux, where drainage is bad and the soil is acid, the peat may accumulate to a great depth—thirty feet or more. This deep peat is very wet, and often bears a true moor vegetation. The dominant plant is often the cotton-grass, conspicuous in summer from the white tufts of woolly hair, which serve as floats for its little fruits. The little club-rush (which like the cotton-grass belongs to the sedge family) is frequently very abundant. Among these grow great hummocks of bog-moss. In the drier places heather grows, and we may find, too, the cloudberry, with its refreshing raspberry-like fruits, crowberry, and bilberry. A beautiful moorland plant is the bog-asphodel, with yellow flowers in early summer and ruddy fruits in autumn.

In the deep peat of the moors plant remains are well preserved, and from them it is possible to follow the changes in vegetation from the time of the glacial epoch. At the bottom of the peat, lying on the gravels left by the retreating ice-sheets, may be found remains of alpine willows and birches, and of the dwarf azalea, all of which are now found only at high levels on the mountains. These are succeeded by stumps of birch and pine from ancient forests. Remains of bog-moss and cotton-grass cover them. Perhaps a colder, wetter climate had, at this point, allowed the bog-moss to flourish so as to prevent the growth of pine seedlings, and so to bring about the extinction of these early forests. In some moors there is a second forest of pine, again engulfed by the moorland plants. A long story of struggle is suggested, the climate and, later, man fighting the forests and bringing about the final triumph of the moors.

The struggle between forest and moor and heath goes on to-day, influenced by many factors. Where an oak wood borders on grass-land or on heath the evidence is plain. There may be no sharp line of demarcation between the two. Extending out from the wood is a fringe of scrubland in which sapling trees, oak, birch, and willow, rise above the general level. A dense mass of brambles, roses, and such smaller shrubs invade the grassy spaces. They in their turn will be suppressed as the trees close their canopy. But often the

marginal zone is curtailed. For, if the pasture is used for grazing, cattle and sheep nibble the seedling shrubs and trees, and prevent them from establishing themselves. The rabbit is especially effective in preventing regeneration. On the South Downs the experiment was tried of fencing in an area of grassland close to a beech wood to keep out the rabbits. In a few years the bare pasture in the enclosure bore a vigorous crop of young shrubs and trees.

GRASSLANDS.—Grasslands are in fact usually a highly artificial type of vegetation in this country, kept in being only by the activity of man and his domestic animals—and of the rabbit, which was introduced by man. We may distinguish between the lowland meadows and the upland pastures. The meadow, on rich moist soil, often along the courses of streams, bears a luxuriant vegetation of grass and herbs. In winter the covering is low, the young shoots growing slowly or resting. In spring there is a resurgence, and by May the meadows may be knee-deep in grasses, among which cowslips, buttercups, lady's-smock, dandelions, and other such flowers 'paint the meadows with delight.' In June the flowering shoots of the grasses rise above the general level, and their clouds of pollen fill the air—to the discomfort of those who suffer from hay fever. Along the edge of field and watercourse coarser herbs, cow-parsnip, valerian, crane's-bill, and others, make a brave show. These strongly growing herbs would invade the meadows proper, but before they have time to flower and fruit the grass is mowed for hay, and they are destroyed: so the ground is preserved for the smaller species.

The upland pastures have a dwarfer herbage. Better drainage and poorer soil prevent the growth of the tall herbs of the low country, and the sheep's sharp tooth keeps even the smaller plants of the hills close to ground-level. Such pastures are seen at their best on the downs, and the chalky soil is favourable to the growth of a peculiarly rich and varied flora. The wiry sheep's-fescue is the dominant grass, and, along with the crested dog's-tail, bent, and others, form a close and springy turf. As examples of the herbaceous plants we may mention the squinancywort, yellow and pink centauries, milkwort, horseshoe vetch, wild strawberry, small scabious, nodding thistle, stemless thistle, rampion, wild thyme, calamint, and ground pine. The bee orchis, spider orchis, man orchis, and twayblade are also found. Some of these plants grow only on the chalk. The downs grasslands are probably extremely ancient; they were the open spaces first inhabited by man in our island, and, indeed, they may represent a natural grassland which never bore forest.

The bracken, given a start, invades such a community rapidly, its tall stems with their close foliage suppressing lower plants. Indeed, the bracken is a serious menace to upland pastures. The fact is that the

bracken is an exceedingly vigorous creature, with which hardly any other plant can compete successfully. It extends from practically Arctic to Tropical zones, and from sea-level to elevations of over 1,500 feet. Like the bilberry, it has the peculiarity of being able to flourish equally well in the shade and in the open. It can spread from one centre at the rate of three to five feet in a year, chiefly by means of buds on its long underground stem. A bracken stretch on a hill-side has been known to double itself in twenty years. It is so insurgent that it can suppress the heather.

We know of many glades where a man over six feet high is quite submerged in the fern, and, besides suppressing natural grasses and heather, the bracken often hides sheep that are in need of the shepherd's attention.

It is much to be regretted if bracken be allowed to usurp land that can be put to better service, and it is important to ask why bracken has been in recent years getting out of hand. Mr. Gordon suggests a number of reasons. For many years there has been little in the way of prolonged winter frost. Bracken is no longer pulled up to be used in thatching cottages; it is no longer collected and burned for potash, of which it contains a considerable quantity; the young parts are no longer boiled for hogs' food; and few households have followed the recommendation that bracken-tops should be used as asparagus.

There has been an unwise toleration of aged and unhealthy heather; and we would quote this important sentence, interesting also in connection with the general theory of the struggle for existence: 'If old heather having a thin crop of bracken through it be burned, the bracken invariably becomes dominant, and ultimately suppresses the heather.' Many authorities believe that it will be necessary in the future to have farms on a bigger scale than ever and with more farming machinery. This is probably true for some Lowland regions and for certain kinds of farming, but in Highland regions there is a great deal to be said for the conservation of the crofter, whose sons and grandsons have been among the most effective citizens of the empire.

In mentioning this we are not wandering away from bracken, for there is a sad saying that 'the bracken is the heir to the crofter.' In a small croft, every corner of which was interesting to the crofter, it was easier to keep down the bracken; indeed, the endeavour to have as many cattle as possible tended automatically to keep the bracken within bounds, for the trampling down is very effective. Moreover, the crofter made much use of the bracken; it is fine bedding for cattle, most effective protection for vegetables against frost, and grand stuff for storing apples in. Bracken has strong antiseptic

qualities, and most insects avoid it like poison. It may turn out to be as important in peace as sphagnum moss has been in war.

On general grounds we have doubts as to the wisdom of branding any virile beautiful creature that threatens for a time to be inconvenient to the practical man, who is often very obtuse.

The emptying of cartloads of bracken into a freshwater loch has been known to lead in a year or two to a great improvement in the number and size of the trout, and clearly one way of checking the encroachment of bracken is to find more use for it.

Already it has been found that the bracken contains within itself properties which may make poor land good and good land better. When burned, it yields ash from which 30 to 40 per cent of potash may be obtained. We are constantly in need of potash for our fields, and bracken produces, when reduced to ashes by fire, a substance worth £25 a ton. It will fertilize our fields and thus help to feed us.

We have by no means exhausted the types of vegetation found in Britain. The links and dunes of sandy coasts, the fens of East Anglia, the submerged and floating vegetation of lake and river are all very different in character and flora from heath, moor, and forest. We do not aim at being exhaustive, but rather at indicating the sort of association into which plants enter with each other, and at showing how these associations come to be so diverse in structure, appearance, and composition. And we would like to emphasize the dynamic aspect of vegetation. The steadfast aspect of forest or moor masks constant change and struggle. In any one climatic region development of vegetation slowly takes place towards a **climax type**, wihch in natural conditions tends to be stable. Over much of our land this climax type would undoubtedly be forest. In fact, however, many influences work against the natural tendency, and in civilized countries the chief of these is man, who needs fields for his crops, and pastures for his flocks and herds. Flocks and herds do not tolerate the regeneration of trees and shrubs. It is said that the whole natural vegetation of St. Helena was destroyed by the introduction of the goat. In a densely populated land like ours there is scarcely an acre, except on the upper reaches of the high mountains, where the hand of man is not felt. Yet in a way it is wrong to look on this as an artificial interference—though we must regret the necessity or carelessness which has felled woods without caring for their replacement. The legitimate needs of man are but the last of the inevitable factors which have moulded the vegetation of our country to its present form.

OTHER PLANT SOCIETIES.—The variety of vegetation types increases as we examine those existing in other climates. The forest differs from ours even in the somewhat similar conditions of North America.

For, though evergreen conifer and deciduous broad-leaved forests occur, both are much richer in species than ours. Where an English woodland may show nothing but one kind of oak, an American may have not only different species of oak, but also various maples, hickories, beeches, poplars, and chestnuts. In warm temperate climates with hot dry summers the forest takes on a different aspect. The nearest example is that of the Mediterranean region. The holm oak is the typical tree in some areas, the cork oak and other evergreen species elsewhere. These trees are all evergreen with hard leathery leaves, well suited to withstand the summer drought. The woods are usually more open than ours, and they pass into a dry heath association, the *garigue*, in which the tall Mediterranean heath is associated with lavenders, rosemary, junipers, and other aromatic shrubs and herbs. Similar forests occur in the dry parts of California. In Australia the leathery leaved woodland reaches its climax in the open forests of tall wattle and gum, species of *Acacia* and *Eucalyptus*.

When the climate is both hot and wet, as in many parts of the tropics, the great rain forest flourishes, the most complex and vigorous vegetation in the world. The tropics have been a forcing-house for evolution, and the number of species is often enormous. Many of these are of great economic importance—mahogany, logwood, and ebony, for instance. The competition for space is keen, and this has led to an astonishing development of climbers—the lianas, the stems of which twist over the ground and round the trees, bearing their foliage to great heights above the forest canopy. Epiphytes too are abundant—orchids, aroids, and bromeliads. Saprophytes live in the decaying matter underfoot, and on the tree branches strange parasites of the mistletoe family compete for space with the lianas.

In arid and semi-arid regions the succession of vegetation often stops short of the development of forest. So we have the steppes of Russia and Asia, and the prairies of America, rich scrub and grassland whose vigorous plants survive the long dry summer, partly by the drought-resisting character of their leaves, partly by the efficiency with which their enormous root systems exploit a deep soil. Where the soil is shallower and the periods of drought are longer we find deserts with their thorny scrub, and cactuses dotting an expanse of bare soil, too dry to support a continuous vegetation. And so we come to completely arid sandy plains, like the Sahara, the only spaces on earth, except the snow-fields of the poles, unconquered by vegetation.

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BOOK IV

MAN

CHAPTER I

WHAT IS MAN?

Man at his best—Man's apartness from animals—Some peculiarities of structure—Man compared with his nearest relatives—Early steps in Man's advancement—The beginnings of society.

MAN AT HIS BEST.—When we wish to think wisely about any form of life we should think of it at its best. If we think of insects, we must not leave out butterflies and bees; if we think about birds, we must not linger too long over poultry; if we think of mammals, we must give more attention to the horse and the otter than to the duck-mole and the rat. So in regard to man, we must think of Newton and Shakespeare *more* than we think of the Bushman or the Hottentot. In trying to appreciate animals, we must not dwell on those which have been stupefied or in some way spoiled by one-sided domestication, like sheep and pigs, for these bear the marks of man's fingers, most eager to produce what will be useful to himself. So in trying to appreciate **Man** we must not (for this purpose) think too much about those who have become degraded, or who have never had much chance to rise.

We must think of the healthiest, wisest, kindliest of mankind if our appreciation is to be just. We must keep Shakespeare's matchless words in mind: 'What a piece of work is a man! how noble in reason! how infinite in faculty! in form and moving how express and admirable! in action how like an angel! in apprehension how like a god!'

We must think of man's achievements. Modern man can weigh a star in his balance and knock a fragment out of an atom. With his telegraph and telephone and television he annihilates distance; with his radiograph he sees the invisible. Modern science has disclosed a long range of electro-magnetic radiations or ether-waves—sixty-two octaves, they say, if we count visible light as one octave—and man is learning to play upon this great gamut. He uses the electro-magnetic radiations of longest wave-length in his broadcasting; he uses those of shortest wave-length for healing his sick by radio-therapy. By sending very powerful electric discharges through the air he has been able to capture the free nitrogen and to build up fertilizers which help the growth of the wheat crop. Thus man may be said to wring bread out of the thin air. Just as his forerunners long ago tamed the wolf

and sowed the wild wheat, so modern man is applying the laws of heredity to the improvement of his domesticated animals and his cultivated plants. Every year man advances a step in the conquest of diseases. The 'minister and interpreter' of Nature is becoming more and more surely its master. *We must think nobly of man.*

MAN'S APARTNESS FROM ANIMALS.—What are the most important characteristics that separate man from the animals? (*a*) Man has **Reason** as well as **Intelligence**, while animals do not get beyond Intelligence. In the section on 'Animal Behaviour' it has been explained that *intelligent* actions, sometimes exhibited by dogs, horses, and elephants, always imply that the animal has put two and two together, has made a little inference or judgment, has appreciated the situation. They mean more than profiting by experience, for an earthworm without a head can do *that*; they mean some understanding of the relations of things. **Intelligent behaviour** requires some activity of mind—some reasoning, though not necessarily much.

But *reason* is at a higher level, for it means working with general ideas, or what are often called concepts, as when we say (to take a very simple case): 'I must see to it that this plank across the stream will bear my weight.' The idea of weight is a concept. It seems very unlikely that any animal, even a chimpanzee, has any clear-cut general ideas, such as 'life,' 'the future,' 'kindred,' 'health,' 'weight,' 'blame,' 'nourishment,' 'offspring.' Animals think in terms of particulars; man can think in terms of universals. An orang may discover the use of a lever, and may pass from a small lever like a poker to a big one like its trapeze bar, which it can just lift; but no one supposes that it understands the *principle* of the lever. As a great authority (Romanes) put it: Intelligence implies *perceptual* inference, while reason implies *conceptual* inference. It need not be supposed, however, that any hard-and-fast line separates the two. Perhaps some of the apes occasionally cross the line.

(*b*) In the second place, man has **Language**, whereas animals do not get beyond speech. This requires some explanation. Many dogs have about half a dozen different barks, which express different things or different feelings. With one word the dog welcomes its master, with another word it announces the presence of an intruder. Similarly rooks have about eight different 'caws,' and the chimpanzee has at least a score of words. But no animal is known to make even a very short sentence. They may express feelings, but they do not express judgments. Children begin this when they are towards two years old. And another feature of language is that it gets beyond inborn or instinctive calls, like the cry of a pewit or lapwing or the croaking of each particular kind of frog; it consists of *socially imitated* sounds which are the recognized symbols for particular things or

feelings. It is certain that the acquisition of language was one of the great gains that enabled man to rise from intelligence to reason. But one must not misunderstand this by supposing that animals cannot communicate news to one another. Even ants do this by tapping with their antennae, and there is a smell 'language' in bees, as well as in dogs.

(*c*) In the third place, man often illustrates **moral conduct,** which is on a different plane from the behaviour of animals. By moral or ethical conduct is meant a controlling of actions in reference to some ideal or general purpose. A fox may control its behaviour in reference to a rabbit which it has set itself to catch, but it cannot be said to control its life in reference to an ideal. Perhaps in a few cases among apes and among domesticated dogs there is the beginning of a glimmering of what 'ought' means, for there are no hard-and-fast lines in evolution; yet on the whole it may be said that animals do not rise from behaviour to conduct. It must be understood, however, that we are not for a moment denying that animals have their virtues, for many of them are affectionate, devoted, loyal, kindly, courageous, and unselfish. These virtues are the springs of good conduct, but the essence of morality is controlling actions in reference to an ideal. This is man's prerogative, though he does not always exercise it.

(*d*) In the fourth place, it is distinctive of man that he has built up around himself a **social heritage,** as distinguished from his flesh-and-blood 'natural inheritance,' to use Sir Francis Galton's phrase. Man is greatly influenced by traditions, customs, conventions, laws, literature, art, institutions, permanent products, and the framework of society itself; and this is the social heritage. There is probably the beginning of some social heritage whenever animals have *permanent products* that persist from generation to generation, as in the case of an ant-hill, or a termitary, or a beehive, or a beaver-dam. When generations overlap in an animal society there may also be the beginning of a tradition. But after allowance is made for these anticipations, the fact remains that man stands apart in building up—for better and for worse—a very important social heritage outside himself.

(*e*) In the fifth place, as one of the wise men of old said: 'Man is a creature who looks backwards and forwards.' He has an awareness of the past and an outlook on the future. Perhaps the first of these qualities may be traced back to the enregistration of the past that we see in some well-endowed animals, like the migrant birds who 'change their season in a night and wail their way from cloud to cloud down the long wind.' Perhaps it has been helped by having permanent products which last from generation to generation. For it must have been of much assistance in securing stability and progress when there

were outside constructions or arrangements, full of meaning or of suggestiveness, which *lasted*, forming a sort of external memory.

Not less important is the habit of looking forward—of adjusting behaviour in reference to a future. We may find hints of this in animals that work towards a remote end, as beavers do when digging a canal which is not of full use until it is finished. Even in a dog that goes off on a longish expedition to the links where it lost its rabbit yesterday, we see the stirrings of a simple purpose, though it may not get much beyond a mental image of its desired booty. In most cases of 'animal foresight,' as in ants and bees storing for the winter, we see the working of instinctive registration, not of intelligent looking forward; but it is difficult to believe that a bird building an elaborate nest has no intelligent vision of the future. Yet however much an animal may show in the way of purposefulness or purposiveness, it never comes near man's genuine forethought. He controls his activities in definitely conscious relation to a desired end, which often involves general ideas or concepts.

To sum up: *The apartness of man chiefly consists in his possession of reason as well as intelligence, in his true language, in his morality, in his social heritage, and in his power of looking backwards and forwards with the eyes of understanding.* He is linked, no doubt, to the rest of creation, yet he stands by himself, especially when at his best.

SOME PECULIARITIES OF STRUCTURE.—In addition to the great characteristics of reason, language, morals, the social heritage, and the power of looking backwards and forwards, there are of course peculiarities of structure which mark man as man. Let us mention a few of these.

(1) Among mammals man alone, after his infancy is past, walks thoroughly **erect,** for we cannot say this in regard to the anthropoid apes, except in the case of the almost thoroughly bipedal gibbons. The other anthropoid apes (orang, chimpanzee, and gorilla) often walk on the ground on all-fours, resting the fore weight on the knuckles of their bent hands.

(2) Man plants the sole of his foot flat on the ground, as in mammals of the bear tribe. This is called **plantigrade.** It is also illustrated by monkeys when they are walking on the ground on all-fours. The same may be said of the anthropoid apes when walking, except that in the orang the hind weight is supported by the outer edge of the foot. As we have already mentioned, the fore weight of orang, chimpanzee, and gorilla is rested on the knuckles, as is occasionally seen among those interesting infants who run on all-fours, instead of creeping on hands and knees in the usual way. After thirty years of observation Dr. Hrdlička, a distinguished anthropologist of the Smithsonian Institution in Washington, found only about three

hundred young children who were known to run about on all-fours in the strict sense. The habit lasts on an average for four months, usually till near the end of the first year. In the strange progression, which is quite effective, the knees are *held off the ground*; the hands and feet are spread out flat; and the body is held more or

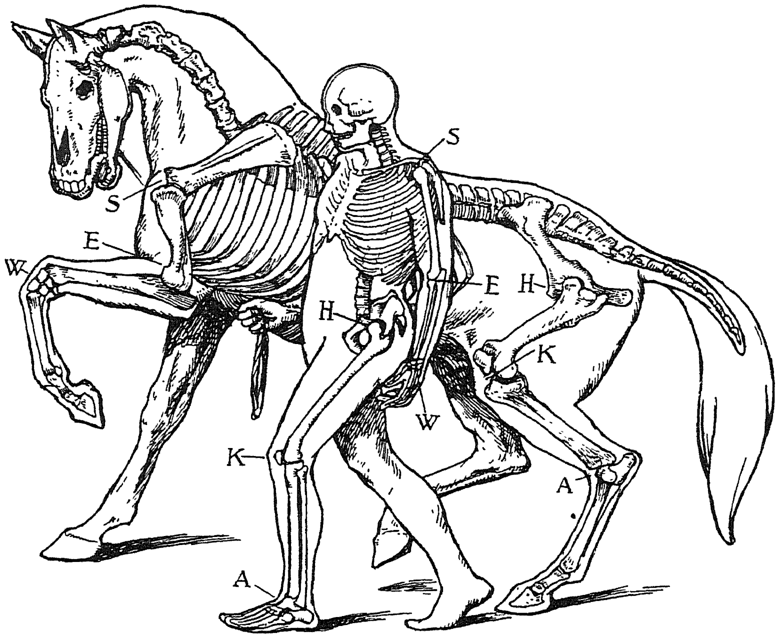

FIG. 440. DIAGRAM SHOWING SKELETONS OF MAN AND HORSE
S, shoulder; E, elbow; W, wrist; H, hip; K, knee; A, ankle.

less horizontal. The 'all-fours' children are very vigorous; there is nothing 'queer' about them. They illustrate a divergence from the usual 'hands and knees' crawling, and this divergence resembles what is seen in monkeys running on the ground. (See Hrdlička, *Children on All-fours*, McGraw-Hill Company, 1931.)

(3) As to the foot, man's big toe is often longer, never shorter than the others, and lies in a line with them. In children there is often a marked prehensile power in the toes, especially in the big toe, which can be used against its neighbour or against the front of the sole. Many a young child can lift a pencil from the ground by using its big toe as a thumb, and can raise it to its hand or to its mouth. The individual toes can also be moved in many cases, so that there are

V-shaped spaces between them. All this recalls the mobility of the toes in apes and monkeys, where it is of obvious advantage in gripping the branches in climbing. Here it may be mentioned that if we arrange the apes in the order of their life in the trees, as contrasted with life on the ground, the order is: gibbon, siamang, orang, chimpanzee, gorilla; that is to say, the gibbon is the most arboreal, the gorilla the least. The prehensile power of the toes in human children usually does not persist as they grow older; but in unsophisticated peoples it may be retained and cultivated. Thus the toes may be used in rowing or in lifting a light object from the ground. In civilized society a man who has lost both hands may learn to hold a paint-brush or the like in his toes. Before leaving the foot we should notice that man has a much better **heel** than monkeys have.

(4) As compared with anthropoid apes, the arms of man are shorter than the legs, but this is also the case in all the Old World monkeys.

There has been much discussion as to the presence or absence of a **tail** in man; but the discussion depends mainly on the definition of the word. The fused vertebrae which support the hip-girdle form what is called the **sacrum.** Behind that there is a fusion of post-sacral vertebrae called the **coccyx,** but it does not project on the surface. A tail in the strict sense consists of *projecting* post-sacral vertebrae and some muscle, all surrounded by integument. Such a tail is present in all human embryos, but as development goes on it normally ceases to project on the surface. In abnormalities, however, the projecting tail persists, sometimes with traces of bony vertebrae, and sometimes quite soft. It may be noted that an external tail is also absent in the anthropoid apes and in some monkeys, e.g. the Gibraltar monkey (*Macacus inuus*).

Let us more briefly sum up a number of other peculiarities of human structure. Compared with the anthropoid apes, man has a bigger forehead, a less protrusive face, smaller cheek-bones and eyebrow ridges, no crests on the top of the skull, somewhat sharply projecting nasal bones, an early fusion of the premaxillae with the maxillae in front of the upper jaw, a true chin (hinted at in the gibbon), more uniform teeth forming an uninterrupted horseshoe without very conspicuous canines. The body is relatively naked. There are no vocal sacs. There is at most a vestige of an *os penis,* that is to say, of a bone in the male copulatory organ (the **penis**). But the greatest difference of all is that man has a much larger and heavier **brain,** as we shall illustrate in the next section in reference to the gorilla. The brain of a healthy human adult never weighs less than about thirty ounces; the average human brain weighs about forty ounces; the heaviest gorilla brain does not exceed twenty ounces. Yet the gorilla's brain has all the parts that ours has.

The last sentence reminds us that while we have in our body many peculiarities, of which a few have been mentioned, an equally important fact is ' the all-pervading similitude of structure ' between us and the anthropoid apes. As far as structure is concerned, there is less difference between man and the gorilla than between the gorilla and the marmoset.

Man Compared with his Nearest Relatives

The ape that comes structurally nearest man is the gorilla, and the resemblance that holds for the body generally is particularly true of the brain. We must rid ourselves entirely of the idea that there is no more than a general resemblance in cerebral structure between apes and man, for it is a detailed and intimate correspondence. Professor Sir G. Elliot Smith, a leading authority on the comparative anatomy of the brain, makes a point of this: ' No structure found in the brain of an ape is lacking in the human brain: and, on the other hand, the human brain reveals no formation of any sort that is not present in the brain of the gorilla or chimpanzee. . . . The only distinctive feature of the human brain is a quantitative one.' This is obviously a very important statement.

The human brain must rank as *the* wonder of the world, for it is the instrument by which the world has become known. It is in actual size one of the largest of brains, being surpassed only by that of the elephants and of the bigger whales. In relation to the bulk of the body man's brain is an easy first among big creatures, but a curious saving clause must be introduced when we take account of pygmies such as some small mice and some humming-birds, for in these the ratio of brain to bulk is greater than it is in man. Professor Lull suggests that in these cases the size of the body has been reduced more quickly than the size of the brain. The converse occurred in some of the giant reptiles, such as *Stegosaurus* and *Brontosaurus*, where the bodily growth was not accompanied by corresponding increase of the brain.

But it is not merely bulk that characterizes the human brain, it is the great increase in the parts that count for most; especially the cerebral hemispheres, and especially the part of the cerebral hemispheres that is the seat of the higher mental processes. The rind or cortex of the fore-brain is not only large, it has become greatly convoluted, like a crumpled cloth, with hills and valleys which would give it a large area if it could be spread out. Metaphorically we may say, for apes and for men, that the cerebral cortex is more wrinkled with thought than in any other mammals. We quote a good sentence from Professor Lull's *Organic Evolution*: ' In its subtle fineness of detail, in its ability to record and often to reproduce an almost infinite number of

mental perceptions, and in all those other resident faculties which together make up the higher intellectual characteristics of humanity, the human brain stands pre-eminent as the most complex structure evolution has produced.'

Region for region, wrinkle for wrinkle, the brain of the gorilla corresponds with man's; but there are great differences in total size, and weight, and in the proportions. The human brain weighs about two and a half times as much as the gorilla's, having about five hundred grammes more cerebral tissue. In the adult gorilla the brain does not weigh more than one two-hundredth of the whole animal, and may be only one five-hundredth of the total. But in man the brain may weigh one-fiftieth of the total—a very remarkable difference, especially when we notice that man and gorilla are not very different in size and mass. Man stands higher than a gorilla, but the length of his head and trunk is about thirty-four inches as against thirty-nine for the gorilla. An average man has a weight of ten to eleven stone; an adult male gorilla weighs about fourteen stone. Evidently the differences are not such as to lead us to attach importance to total dimensions as a factor in the cerebral differences between gorilla and man.

A full-grown man may have a brain two and a half times heavier than that of a full-grown gorilla, and there is a corresponding difference in the size of the brain-cavity. This cranial capacity is never less than fifty-five cubic inches in any normal human subject; while in the gorilla, the orang, and the chimpanzee, the maxima are thirty-five, thirty-two, and twenty-nine respectively. If we took a really big-brained man the difference would, of course, be much more striking. But, as every one has a wholesome suspicion of mere size-differences, it is necessary to explore further, utilizing such guides as Sir G. Elliot Smith.

The fore-brain or cerebrum has grown so large in man and anthropoid apes that it hides all the rest of the brain. It is covered externally with a thin convoluted layer of grey matter consisting of millions of nerve-cells. It is a thin layer, from a sixteenth to a fifth of an inch in thickness, but if it were spread out it would cover over a foot and a half square.

This **cerebral cortex** is the seat of many of the higher mental processes. It weighs about 660 grammes, but if we subtract the supporting tissue and the blood-vessels, the weight of the essential elements—the neurons or nerve-cells—would be only about thirteen grammes. There are about 9,200 millions of nerve-cells in this cerebral cortex, and yet they could be packed into about a cubic inch—certainly the most remarkable cubic-inch-full in the world, for its elements when living form the instrument with which the mind of man measures the universe. When we think that we have in our cerebral cortex about five times as

many nerve-cells as there are people living in the world, we are face to face with a quality more important than size, namely, intricacy of organization. The possibilities of interrelations between these millions of neurons are inexhaustible.

In all backboned animals the brain shows the same five main parts, but in placental mammals, as distinguished from birds and reptiles or lower forms, there is in the cortex of the fore-brain a special development of a unifying area or organ, which Sir G. Elliot Smith has called the **neopallium.** It is the area into which (*a*) nerves from the sense-organs bring tidings, in which (*b*) the stimuli are somehow unified and registered, and from which (*c*) commands are sent out to the muscles.

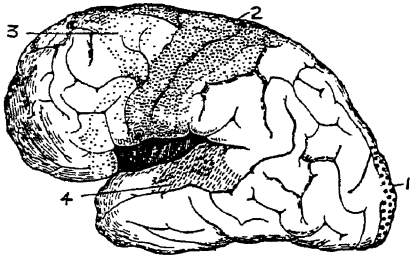

FIG. 441. HUMAN BRAIN, SHOWING AREAS OF LOCALIZATION IN CEREBRAL CORTEX

1, visual area; 2, area of general sensations; 3, motor area; 4, auditory area.

The neopallium meant *a new unifying organ*, and it is of obvious interest to know that the human brain has a vastly greater area of neopallium than that of the gorilla. For man's neopallium is at least three or four times larger than an ape's, and some would say six times. This is the physical or physiological side of the fact that man is so much more of a personality. For the neopallium is a unifying organ.

But Elliot Smith has shown by an illuminating study of the minute structure of a series of brains that in the higher reaches among mammals the neopallium undergoes a very marked improvement. This advance, seen when we compare the brains of jumping shrew, tree-shrew, tarsier, marmoset, monkey, ape, and man, is marked by a decrease of the olfactory area and an increase of the visual, the acoustic, the tactile, the associative, and the manipulative areas; and it is to be thought of in connection with the emancipation of the hand to become a tool, with the reduction of the snout, and with the gradual acquisition of stereoscopic vision. By gradual advancement for millions of years the simian brain was reached, and then the brain of the vaguely known common ancestors of anthropoids and hominoids, and then the unknown brain of tentative men, and then the brain of *Homo*.

There seems no reason to suppose that the neopallial evolution has come to an end, least of all for *Homo sapiens*, who seems to be more variable than the apes, and in whom, at any rate, any progressive brain variations that occur have more chance of finding foothold.

We cannot study Elliot Smith's series of brains without feeling how inaccurate and unfair it is to speak of man's evolution as a 'fluke.' It was a critical event in man's history when he finished his **arboreal apprenticeship**, in which he learned much, and became definitely terrestrial. Thenceforward he had to trust to his wits, and selection was predominantly in reference to mental qualities. The anthropoids remained more or less arboreal, and they have remained less progressive.

But the recent studies of Professor Köhler and others have convinced naturalists and comparative psychologists that apes are much abler animals than was previously supposed. Chimpanzees will pile one box on the top of another, to the number of four, to reach a banana hanging from the roof of their cage. After many failures to use pieces of bamboo rod to retrieve fruit lying outside the bars, a chimpanzee hit upon the device of sticking a short length into the hollow end of a longer one, and thus reaching the desired booty. An orang discovered the use of a wooden lever, and then proceeded to find other levers of different dimensions, ending with a trapeze bar in the cage, which he used to force apart two iron rods, so that he could put his head out and look round the corner to see what his neighbour was doing!

But while we admire these and other achievements of apes, we cannot but be impressed with their limitations. Even clever chimpanzees are balked by practical problems that a child of three could solve. Why is this? Their brains have a much smaller neopallium, that is the general reason. Secondly, though they have many sounds, even words, they have no true language. That is to say, they do not use socially imitated sounds to express judgments. They seem to have a very poor repertory of mental images; they can rarely solve a problem unless the materials for the solution are within their immediate visual range. Theirs is a sort of picture-logic. They have intelligence, but they are only at the frontier of reason.

But we must not forget their complex life of feeling, which includes not only affection and anger, but such subtle emotions as jealousy and kin-sympathy. They are nearer us than we thought, and yet how apart man is!

Early Steps in Man's Advancement

We are accepting the view that the pre-human ancestors of man lived more or less in the trees, and gained much from a prolonged arboreal apprenticeship. But the critical step was taken when these shadowy beings left the trees and became terrestrial, for there is reason to believe that the hominoids or 'tentative men'

emerged on terra firma, leaving the anthropoid stock more or less arboreal.

What we wish to attempt here is a brief survey of the most important steps that were taken when *Homo* began to come to his own, when 'tentative men' were evolving into true men. Each of the steps might be the subject of a book, and in some cases, indeed, the book has been written; what we must be content with here is simply an outline of the step-by-step advance.

THE QUEST FOR FOOD.—Man's first need was to secure a constant supply of food, for precariousness in meals is neither pleasant nor wholesome. He would begin with what was readily available, and for ages before he had a fire his meals were perforce uncooked. He would gather fruits, seeds, molluscs, eggs, wild honey, and the like.

There are two eloquent facts in regard to man's early quest for food. In the first place, we owe him a debt of gratitude for beginning the long process of discriminating between the wholesome and the deleterious, an experimenting and sifting which must often have cost him his life. In the second place, primitive man began to learn, in this quest for food, that consequences are unpitying. It was a training in scientific method, whose lesson, even to-day, is often nothing more than, 'If this, then that.' Man began to discern the uniformity of Nature—for hemlock is always poisonous and the false oyster (*Anomia*) is always bitter.

SAFETY FROM ENEMIES.—On terra firma primitive man had more enemies than his ancestors had among the branches. He had to pit brains against brawn, and one of his first steps was to get to know the ways of deadly creatures and to learn how they could best be faced or avoided. Pitfall-traps must have appeared very early, and refuges of various kinds were doubtless prepared when the risks were great.

SHELTER FROM THE STORM.—Primitive man was doubtless healthy and vigorous, but we cannot think of him as very strong, not as compared with a gorilla, for instance. His chief strength was in his mind, not in his muscles. Therefore we think of him discovering or making shelters against all sorts of storms—snow, sand, hurricane, flood. A great series of spacious and dry caves, like those of Dordogne, meant safety for ages, and we can see there, from the drawings on the walls, that the safety was often used as a shield for art.

No small part of the early struggle for existence was this endeavour to meet the vicissitudes of callous Nature, and we can readily understand that the sifting would favour variants in the directions of alertness, foresight, and ingenuity. We are a little apt to forget how true to Nature is the parable of the builders, with its picture of the destruction of the careless and reward of the wise. There was the sensible man who built his house on rock. The rain came down, the

floods rose, the winds blew and beat upon that house, but it did not fall, for it was founded on rock. And there was the stupid man who built his house on sand. The rain came down, the floods rose, the winds blew and beat upon that house, and down it fell—with a mighty crash (cf. Matt. viii). Such was the struggle for existence even before *Homo sapiens*!

USING AND MAKING TOOLS.—There are a few records of the effective use of sticks and stones by apes and monkeys, and there is no doubt that a chimpanzee will sometimes whittle the end of a stick with its teeth so that it can fit into the hollow end of a bamboo rod. But what is merely hinted at in apes and monkeys was an early habit of 'tentative men.' Stones, tusks, bones, shells, and the like were used as tools or as weapons. One of the earliest was the 'scraper,' in some cases probably true to its name, being used to scrape the flesh from the bone, or the fat from the hide, or the husk from the fruit. A hammer made from a suitable stone would be welcome to split the coco-nut or to crack the carnivore's skull; and the modern schoolboy's delight over his first knife may be unconsciously reminiscent of tentative man's experience of several hundreds of thousands of years ago. The first *found* knives were splintered stones with sharp edges; the first *made* knives were perhaps artificially chipped flints, or strong pieces of shell.

CLOTHING.—It was probably to woman's credit that in cold regions or seasons she made the first clothes, not out of fig leaves, but out of the skins of furry animals. The baby had to be kept warm, and for adults very long ago the fur coat had, as it has still, an aesthetic as well as a physiological appeal. Many simple peoples use pliable bark as part of their clothing, and others have learned to plait long leaves and fibres. Along with clothing we may include, in a mere glimpse like this, the material for a tent, a water-bag, and sandals; and a very early 'hit' must have been string made out of climbing plants and grasses, strips of leaf and torn-out fibres, sinews and strips of skin. Given a knife to cut with and string to bind with, what might not man accomplish?

CULTIVATION.—Also to woman's credit, we believe, were the first attempts at gardening, which led on to cultivation and agriculture. When the men were away hunting, the women, idealized in Ceres, Demeter, and others, started cultivation—growing some favourite plants around the hut or outside the cave. From small beginnings what great results have come!

In *Early Man* (1931) Mr. Harold J. E. Peake, a distinguished anthropologist, speaks of the woman who first collected the seeds of wild grasses and laid the foundations of civilization. We commemorate her every harvest season in our staid country when we cart to the barn the effigy of the corn-goddess. 'It was, we may well believe, some

time between 6000 and 5000 B.C. that this woman collected the seeds of barley and emmer, and scattered them upon a cleared surface on the mountain side, where they were watered with the dew of Hermon that descended upon the mountains of Zion, so that the seed which she had cast upon the hill-side she found increased a hundredfold after many days.'

DOMESTICATION.—To woman also some authorities ascribe the early essays in domesticating animals, for was she not the tender foster-mother of lovable young beasts from the forest? If this be so, the hunter deserves a share in the credit, for it was he who carried the wolf-cub home after he had killed its mother. There was more than a whim in the impulse that led him to take this first step towards the domestication of the dog—which was the earliest animal to accept man's tutelage.

UNIFORMITY OF NATURE.—To rank an appreciation of the regularity or uniformity of Nature as one of the early steps in man's advancement may seem, at first sight, to be out of perspective. For it obviously implies an intellectual gain; it was the beginning of science. But that beginning was so essential to further material progress that we feel bound to give it its place. In all probability it was through a recognition of the reliable sequence of the **seasons** that man got a grasp of the idea of the orderliness of Nature. The march of the seasons was a great object-lesson, suggesting the uniformities on which science has built. In the well-known picture that Aeschylus gives of primitive man there is emphasis on the intellectual importance of recognizing the sequence of the seasons. He tells us how 'First, beholding, they beheld in vain, And, hearing, heard not, but, like shapes in dreams, Mixed all things wildly down the tedious time, Nor knew to build a house against the sun With wickered sides, nor any woodwork knew, But lived like silly ants, beneath the ground, In hollow caves unsunned. There came to them No steadfast sign of winter, nor of spring Flower-perfumed, nor of summer full of fruit, But blindly and lawlessly they did all things.'

Later on, after the lesson of the march of the seasons had been learned, there came to man a finer intimation of uniformity from a study of the movements of the heavenly bodies; and we cannot forget Poincaré's remark that if the earth had been beclouded, science would never have begun at all.

USE OF FIRE.—We must not give the use of **fire** a *very* early place among man's steps of advance, for we know that the Stone Ages lasted for many millennia, and it seems unlikely that man with fire in his service would be very long before he began to use metals for his implements and weapons. But the use of fire began early, and it opened many a door.

How the discovery was made remains uncertain. Perhaps it was suggested by the tree struck by lightning; by the flames of a volcano, by two branches rubbed together by the wind in the woods. Perhaps the discovery was made in the course of flint-chipping, when the spark struck off was caught in 'touchwood' from the decaying tree or in resinous dust from the branches that insects had bored. Perhaps fire was made by rubbing a hard stick in a horizontal groove fed with resin dust, or by twirling a vertical rod round and round in a hole in a log. When fire was made it was one of woman's early duties, idealized in Vesta's temple, to keep it from going out.

How great an invention was fire-making! For without fire there could not have been any use of metals; without fire there could not have been any cooking except in hot springs and volcanic ash; without fire many enjoyable parts of the earth would have remained practically uninhabitable by man; without fire man's knowledge and power would have remained sadly frozen. [See Thomson's *Modern Science* (Methuen, 1929), Chapter XXI, 'Man's Early Inventions.']

COOKERY.—Primitive man depended on raw food, such as fruits, honey, oysters, and eggs; but with fire at his service he began the unending series of experiments in cookery. This again was probably to the woman's credit, though the best *chefs* have always been men. The advantages of primitive cookery were that it made many foods safer, more palatable, more readily chewed and digested, and less liable to go quickly wrong in warm weather. Roasting in the hot ashes of the fire was one of the most primitive methods, and from this as a beginning there is a long story of advance to which we shall briefly refer later on.

POTTERY.—Very ancient and very persistent is the custom of encasing the animal food—say a plucked bird or a skinned small mammal—in a covering of clay, before putting it among the hot ashes of the fire. This simple device, which gipsies still practise in this country, prevents the food from being burnt and saves the juices from being wasted. It also points the way to the discovery of the pot, for the baked-clay casing is very suggestive. Dishes of various shapes and sizes would be made for future use, and pottery began. The dome-shaped dwellings of certain white ants are used in some countries as ovens, and turned upside down to form tubs; models for various forms of cup and saucer, pot and pan, are not far to seek in Nature, as in shells, horns, gourds, coco-nuts, and carapaces.

Here we may include a reference to building material of earthy origin. Adobe, so much used in ancient California, is sun-dried earth with some coherence due to fibres; and bricks mark an obvious improvement. But long before there was building, there were homes in caves,

in tents, in huts with wicketed sides. When houses were built it became easier to imitate the ants and bees in laying up stores for the winter and for the evil day, for there was not in caves much room for granary or barn, and the dwellers in tents rarely store at all.

MEANS OF TRANSPORT.—At a very early date primitive man must have had an open eye to various ways of reducing distance and facilitating the transport of booty. It is an eloquent sight to see the paths of animals, even of ants, in the forest; and the economy of road-making must have been an early discovery in the advance of mankind. The partnership established in domestication led to the different kinds of 'beasts of burden.' The making of bridges, which saved days of tramping, would be suggested by the great trees borne down by the flood and stranded crosswise in the shallow of the stream.

Tylor, one of the founders of anthropology, speaks of the evolution of the boat: 'He who first, laying hold of a floating bough, found it would bear him up in the water, had made the beginning of navigation.' As we have said elsewhere: 'Let us picture the native astride on the log, so apt to turn turtle; the shaping and balancing of the log; the joining of log to log to make a raft; the hollowing out of the log with knife and fire; the use of a dug-out tree big enough to hold several adventurers; the use of hides to make a skin canoe; the holding up of a mat or blanket to catch the wind; the supporting of the primitive sail by a mast; and so gradually onwards till there emerges before us the fishing-boat—so important in opening up the world. Most of the big ideas of sailing craft were put into practice before recorded human history began.' (See Thomson, *op. cit.*, Chapter XXI, 'Man's Early Inventions.')

PRIMARY OCCUPATIONS.—From very early times there began a specializing of the primary occupations—hunting, fishing, shepherding, farming, and so forth. This differentiation depended in part on the means of livelihood afforded in various regions and partly on the dominant moods of the various human types. There are persistent hunters still, apart from those who follow the chase in the literal sense, and persistent shepherds who tend no flocks. It is important to recognize the masked persistence of the ancient types all through the history of civilization, and also the way in which the dominant occupation has been congruent with other expressions of the hereditary nature, as in the religion, the art, and the philosophy.

MANY INVENTIONS.—We have tried to suggest the interest of peering into some of man's early steps, but there are many inventions which we have not mentioned, far-reaching as their influence was. There is, for instance, the **wheel**, which is very difficult to account for. Many suggestions have been made, but they are very unconvincing—the cylindrical rollers made of cut lengths of tree-stem, the cross-

sections of trunks, the rounded pot-hole stones, the wheel-like ammonite fossils, and so on. Perhaps the likeliest origin is in the clumsy plank-wheel, made of firmly fastened planks, cut peripherally into a circle. Into such origins it will be found very interesting to inquire: thus we may suggest as problems for the student the invention of the bow, the specialization of weapons against other men, the first writing, the melting and moulding of metals, the earliest art, the foundations of medicine.

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The Beginnings of Society

No paralysing difficulty confronts us when we ask how human society began. For if we believe that 'tentative men,' hominoids but not yet true *Homo*, arose from a stock common to them and to the anthropoid apes, we are linking mankind back to creatures that are nearer the social than the solitary. Gorillas sometimes prowl about in small troops, and chimpanzees are very fond of one another's company; and while it cannot be said that any anthropoid apes live in communities, they are related to monkeys among which the social note is often sounded. We are not of course including any living monkeys in man's lineage—no one believes *that*—but they represent a kindred stock, specialized for arboreal life, and they are often more than gregarious. They sometimes combine to drive off intruders; they will tear an over-venturesome eagle to pieces; they sometimes unite to raid an orchard; and they can execute a retreat not in a disorderly rout, but with some exhibition of social tactics.

In any case man is a mammal, belonging to a stock that has often shown an aptitude for becoming social. We think of beavers in their 'village,' prairie-dogs in their 'town,' wolves in their pack, elephants in their troop, dolphins in their school, wild horses in their herd. It is plain that the emergence of man's sociality is not the puzzle it would have been if all the mammals were like the cats that walk alone.

There is much truth in Rousseau's saying: 'Man did not make Society; Society made man.' For it was in a social environment that man's characteristics—such as reflectiveness, language, and gentleness—would have most chance of evolving. It is possible to think of man emerging as an unusually big-brained mutant or genius

in a stock that practised the 'each-for-himself' way of living, but it is impossible to think of his continued evolution apart from a social heritage, in which he enregistered gains outside himself. But Rousseau's saying does not answer our question as to the origin of the primitive society in which primitive man came to his own.

It is not improbable, as Barrell first suggested, that Man and the Himalayas arose simultaneously, towards the end of the Miocene period. Sir Arthur Smith Woodward tells us that 'as the land rose, the temperature would be lowered, and some of the apes which had previously lived in the warm forest would be trapped to the north of the raised area.' As the forest shrank and gave place to plains, the pre-hominoids had to adapt themselves to living on the ground. If the residual apes had not remained so largely arboreal they might have evolved further than they have done. Not that they have been laggards; the point is that they have evolved on a semi-arboreal line of their own.

We see, then, that the early forerunners of *Homo* essayed a new environment, and this must have been a good reason for their standing by one another socially. There is no reason to think of them as weak or timid or lacking in resourcefulness—their pedigree disproves the idea—but they were adopting a new rôle on terra firma and off the trees, with formidable wild beasts as competitors. Their hope was not only in their wits, but in their solidarity. Union is strength.

Another reason for clubbing together may be found in the prolonged human infancy with its appealing helplessness, for this involved self-subordinating division of labour. The struggle for existence was too keen to admit of an isolated human family. Thus arose a self-preservative linking of families into a simple societary form.

From first to last two features are essentially characteristic of a society. The first is that the community can achieve what is far beyond the reach of the individual—it may be digging pitfalls or building a stockade round the settlement to lessen the assaults of wild beasts; it may be clearing out a cave; it may be rolling the tree down to the side of the lake. It matters not; what one man could not do, even with his wife to help, could be achieved by the social effort of the primitive community.

In the second place, as is so well expounded in Dr. Trotter's *Instincts of the Herd*, the existence of a society implies a shield to individual members who could not stand alone in the struggle for existence. Ant communities are known in which the members of the ruling class are not only unable to forage, but have actually to be spoon-fed by their slaves. This is an instance of the seamy side of a sheltering function which is in many other ways beneficial. Similarly among the white ants or termites there is a caste of soldiers whose

jaws, transformed into weapons, are unable to chew the wood that forms the ordinary diet of the community. These soldiers could not survive for a week apart from the society. No such extreme cases could occur among primitive men, though they form a familiar menace in civilized society; but the existence of a little community made life more secure for the children and for the aged—thus contributing to stability at both ends of life's trajectory. For children mean a future and the aged mean a conservation of the lessons of the past and the building up of tradition.

No doubt many solitary mammals, such as otters, are unsurpassed in their parental care, but this involves an extraordinary preoccupation, especially on the mother's part. It may be compared to the domestic preoccupation of the solitary shepherd's wife in a lonely part of the country. Even a simple society, with its incipient division of labour, is more economical. And economy in the use of energy is always on the line of progress, provided there is no loss of efficiency—which in this particular case would include parental affection.

The aegis of society would normally shelter the children and the old people, for infanticide and killing the aged are to be regarded as extreme instances of the pathological aberrations that so often attend advances; but it would be also extended to various kinds of new departures for whom a purely individualistic struggle for existence would be apt to be fatal. No doubt there was much natural selection, and individuals deficient in eyesight, hearing, sense of direction, swiftness, endurance, foresight, wide-awakeness, and vigour would tend to be eliminated in the competition with wild creatures and in the quest for food.

But our point is that even a simple society might hold a shield over, for instance, the primitive artist, who was too dreamy for the chase, yet was worth looking after for the music he made, or the drawings on the walls of the cave, or the carving of the spear-shaft, or simply for his pleasant conversation, which Emerson speaks of as one of the chief ends of life.

And here we are not leaving the path of common sense if we say that part of the **survival value** of an incipient society is to be looked for in the opportunity it afforded for talk. These tentative men were the outcome of a trend of mammalian evolution leading to a high differentiation of the part of the cerebral cortex that has to do with vision, visualization, touch, manipulation, experimenting, and memory.

As we have seen, Elliot Smith points out that man's brain, as compared with a gorilla's, shows an enormous increase in the three parts of the cerebral cortex that have to do with muscular skill, with speech and with its comprehension. These are the three areas that reach their full development *last* in the human child. We cannot doubt that

early man was wont to convey information to his fellow-huntsmen by marks on trees and other visual symbols, and that, like many animals, he had specialized sounds expressive of emotional states and of outside things like ' enemy ' and ' food.' But it was a great advance when he began making sounds as auditory symbols of things and attributes, and began copying them from his neighbours. Speech is the use of socially significant sounds, and it rises to **language** when simple sentences are formed—expressive of judgment or inference.

Now, the use of words as symbols became an organon of thought, and opened the way to otherwise impossible intellectual advance. It led on to general ideas as distinguished from mental images—a kind of thought-algebra in advance of a kind of thought-arithmetic. It led on to Reason, which may be defined as Intelligence at a higher power—involving general ideas. Part of the survival value of society was the possibility it afforded of comparing notes around the fire—and beginning to build up generalizations.

CHAPTER II

MIND

What is mind?—Man not a machine—Man's greatness.

What is Mind?

There are two grains of truth in the old jest, which pleased us so much in college days: 'What is Mind?'—'No matter'; 'What is Matter?'—'Never mind.' For in the answer to the first question there is the truth that mind is immaterial and imponderable. It is not even very measurable, except through its echoes in the body, for who can measure the measurer?

The truth, spoken in jest, in the answer to the second question, is just this—that matter could never, and can never, give origin to mind. By no intellectual sleight of hand can we juggle mind out of matter, unless, like the conjurer, we have already sneaked it there. We do not know much about matter—do we?—except what our mind has told us. There is surely a better philosophy in the old wisdom: 'In the beginning was Mind.' 'And without Mind there was nothing made that was made.' It is hard to go beyond that.

While we cannot define mind, we may describe it as *the inner conscious life of feeling, purposing, and thinking*. We are self-aware creatures, yet we must not think of our mind as something that we possess, that we can take out and look at—like our watch, for instance. For our mind is just the inner or subjective side of our life. In man's case, whatever it may be in the higher animals, there is built up, as we all know, a unified 'self' or **personality,** which sometimes thinks and feels as if it were a unity. Yet we are probably deluding ourselves if we picture our mind as like a conductor ruling our little orchestra of mental activities. Our embodied mind is our inner self-aware life, capable of unified agency just like our enminded body, not that either is invariably successful. There are mental as well as bodily mutinies; and sometimes, as St. Paul said, the law in our members wars against the law in our mind.

That the higher animals have minds no impartial inquirer can doubt, for they have feelings (such as affection and anger); they have purposes (as when they build a shelter or lay up stores for the winter); and they have intelligence (as when a chimpanzee joins two bamboo

lengths together to make a rod long enough to retrieve a fruit otherwise out of reach). This is not saying that the feelings, purposes, and intelligence of the dog or the horse are the same as ours, for they are not; but unless we credit the higher animals with minds, the world of life is a weird conundrum.

The stream of inner life becomes a slender rill when we trace it downwards and downwards in the animal kingdom; and we lose it altogether, or almost altogether, among the plants; yet unless we adopt the view of some philosophers, that mind came into the realm of life like a bolt from an elsewhere blue, we must think of *patent* mind as gradually emerging from *latent* mind which was resident even in the lowest forms of life, though it could hardly find recognizable expression there.

Is this not getting beyond science? Perhaps, but it is getting back to one of the oldest of philosophical speculations—that there is nothing in creation without some germ of mind. Perhaps there is a fallacy lurking in the phrase, 'Inanimate Nature'; perhaps there is nothing that can be called *inanimate*.

For centuries man's mind has been trying to look at itself (introspection); and in modern times it has been inquiring into its own development (partly revealed by child-study), and into its own evolution (by studying primitive peoples, who are our contemporary ancestors, and the minds of the higher animals), and into what is revealed by ingenious methods of psycho-analysis. So that there has developed a rapidly growing science of **psychology**—the science of the inner side of behaviour. What does it tell us?

In many ways it seems useful to compare our inner or subjective life, which has its home in the cortex of our fore-brain, to a stream—a stream that is somehow more or less aware of itself. The upper layers of this wondrous stream are very clear, and they bear tidings or **sensations** from the outside world and from the recesses of the body. These impressions are often very pleasant, for we enjoy the sunshine, and our pulse quickens before beauty.

A little below the surface the stream carries the pictures we make, the mental images that form our gallery of **percepts.** Sinking deeply into the waters come well-laden vessels, which have been carefully built in the upper reaches of the river; these are our **abstract ideas** or **concepts,** and according to the number and well-builtness of this kind of craft our minds are rich or poor. 'My mind to me a kingdom is.' Deeper down, and not seen from the surface, unless they rise like submarines, there are our **memories,** some sacred and others shameful, most of them moving very slowly, though others hurry away like dreams when one awakens.

The stream has its waves and often its song, its sunlit sparkle and

its deep shadows—these are our **emotions.** In earlier years they are more noticeable and nearer the surface. Often they become attached to vessels of stronger build, as the aesthetic thrill to beautiful pictures, and the arrows of desire to the bow of endeavour.

Of the last—our **purposes**—who knows what image to use? They correspond to the directing of part of the current along a particular channel, where the momentum is greatly increased, turning the mills of everyday tasks, or bearing a fleet out into the sea of adventure.

In the deeper, darker waters of the stream, beyond the reach of the light of consciousness, there are the snags which we call **repressed complexes.** Sometimes in dreams, sometimes when we are caught unawares, these repressions may rise like whirlpools to the surface, giving us no end of trouble.

Deeper still, submerged but not repressed, is the **primary unconscious,** our legacy of racial predispositions, our instinctive likes and dislikes, our plus and minus prejudices, and what not, hugging the bed of the stream, yet often influencing the surface-flow for better and for worse.

What a wonderful stream is our mind! And we were almost forgetting the rainbow-coloured foam-bells of **imagination**—fugitive in themselves but often the forerunners of purpose. These are perhap the finest crafts on the thronged stream of consciousness.

No one, outside of prophets, priests, and kings, ever changed the face of civilization more in a lifetime than did Newton with his mathematics. Yet he was one of the most miserable infants ever seen, they say, and of how many weaklings and invalids must it be admitted that they have been makers and shakers of the world! The body may be fundamental, and we all admire a fine one, but *the mind is supreme.*

It is, indeed, the brain that counts, not the body in general, and especially the shallow, much wrinkled, outer layer or cortex of our fore-brain or cerebrum. In this **cerebral cortex** there are in an average man five times as many nerve-cells as there are people living in the world to-day, and it is among these, with their incalculable possibilities of interlinking by means of delicate living branches, that the mind is, so to speak, at home.

Though we cannot be as definite in our statements as we should like to be, we may say that a fine mind goes with a fine brain. A great step was taken long ago, among some of the higher mammals, when the cortex of the fore-brain began to come to its own, and when the nerve-centres or central offices for sight, hearing, manipulation, and intelligence began to predominate over those of smell and the like. This advance is particularly marked in a series of arboreal mammals, beginning with tree-shrews and tarsiers, rising through half-monkeys

and true monkeys, and finding its climax in the anthropoid apes, pointing on to ourselves.

There is a close correspondence between the complexity of the brain and the intelligence of the behaviour; and no one doubts that the two realities—brain and mind—have evolved hand in hand, though we cannot clearly explain how they are related. The same is true of the individual development, for, although we do not acquire any fresh nerve-cells in our brain after we are born, there is an increase in the complexity of interrelations, and this goes on step by step along with the growth of the child's mind, which we watch from month to month with so much delight. It is one of the most beautiful of dawns.

In the dim and distant past, when the ancestors of man were serving their arboreal apprenticeship (p. 1270), the evolution of the mind and the brain progressed along with the emancipation of the hand (from being a walking fore-limb), along with the shortening of the smelling snout (no longer needed to poke into holes), and along with the shunting forward of the eyes (so that vision became more and more stereoscopic). Thus the individual development of the child must include a succession of appropriate bodily trigger-pullings if the best is to be made of the mental inheritance. And yet, when all is said about this normal working together of body and mind, brain and mind, we have to admit that things are not so simple as some people would make out. Some infants born two months before their time, and thus seriously handicapped, have grown into very able men—Thomas Hobbes, for instance. Some cripples from birth, with little experience of bodily activity, have had very fine minds.

In some respects the mind seems to pursue its own course of development, as if it were in some way independent of its bearer—whether we call this bearer the body or the brain. In many respects the mind is made as much as born; it is in a deep way a social product.

We cannot depart from the findings of the science of heredity—that mental characteristics are inherited like those of the body, that you are not likely to gather mental grapes off physical thorns, or figs off thistles. Yet we feel compelled to claim a remarkable independence for the mind. For it is not quite true that you cannot make an intellectual silk purse out of a sow's ear. You cannot make a genius out of a humdrum child, yet wonders can be worked by improved education, exercise, and conditions of life. Deep indeed was Shakespeare's insight when he made Prospero say of Caliban: 'A devil, a born devil, on whose nature nurture will never stick.' And even if it did stick, it would not change the hereditary nature as regards the legacy to subsequent generations.

The science of heredity has made great strides during the last half-century, and its results go to show that no amount of improved nurture

can give a man a new talent, though it may double the value of those five or ten talents with which he has been born. Our point is that the mind is even more amenable than the body to nurture.

The great fact in the long story of Organic Evolution is the gradual emancipation of mind age after age: and it looks as if this were wrapped up with the evolution of more and more intricate nervous systems. The brain does not secrete thought, and yet a certain complexity of brain seems to be necessary if the mind is to express itself. Who dare say that this twofold progress is going to stop? And even if we cannot prove that there is any increase in the maximum of man's mental stature as the centuries pass, it looks as if the average were being raised. Einstein may not be taller than Eudoxus (whose name is now hardly known), or Rutherford than Archimedes, but there are more minds to-day with an understanding of what the giants are after.

This brings us back to the question of questions: Is the mind a musician playing on the instrument of the brain (even Aristotle did not know the rôle of his big brain!); or are mind and brain like the inseparable two sides of a shield, the concave and the convex surfaces of a dome—the psychical and the physical, the mental and the material aspects of one reality, which is our life? Perhaps when our activities seem all of the body, we are body-minds; perhaps when our activities seem all of the mind, we are mind-bodies. But whichever answer be nearer the truth, both are right in this: That mind and body are both real. Ideas, Hegel said, have hands and feet. The mind is supreme.

Man not a Machine

After what we have said in regard to the greatness of man's mind, it may seem strange, as indeed it should, to use a phrase like the title of this section. Yet from time to time the announcement is made that man is, to all intents and purposes, a machine. It is usually a physiologist who announces this damnable heresy. Thus the late Professor Jacques Loeb, who might well be called an experimental genius, compared man to Hammond's 'Dirigible Dog.' This was an ingenious contraption with an automatic electromotor and a delicate steering gear that responded to the direction and intensity of external illumination shining into eyes made of selenium, an element exquisitely sensitive to light. When a visitor with a bull's-eye lantern came into the dark room where Hammond's 'Dirigible Dog' reposed, the light automatically switched on the motive power and the dog advanced. When the visitor stepped to one side the dog followed, the direction being determined by the angle at which the rays of the lantern entered the selenium eyes. Thus the contrivance chased the visitor round the

room until the extinguishing of the lantern put it to sleep again. According to Loeb, the activity of a real dog is describable in similar physico-chemical or mechanical terms, though the living creature is admittedly much more intricate than Mr. Hammond's contrivance.

It should be noted that Loeb did not go the length of saying that the living dog and the living man are machines and nothing more, but he denied that 'mind' counts in behaviour. And there are some able-minded men who have persuaded themselves that consciousness is no more than the whistle of the engine's safety-valve, and that feelings have as little to do with the current of life as the foam-bells on the surface of a stream with its masterful flow. Our position, that the behaviour of the dog or the conduct of the man is unintelligible unless one credits both with some sort of 'purpose,' is regarded by the extreme behaviourists as a relapse into an outworn psychology!

The theory of man as mere mechanism, *l'homme machine*, has lasted so long, or reasserted itself so often, that there must be something attractive in it. What truth is there in the heresy? There is no doubt a chemistry and a physics of the human body, which may be some day reducible to mechanical terms; and the chemical and physical processes that go on without ceasing in the living body can be brought more or less into line with those of an oil-engine or the like. But *the living body is a self-stoking, self-adjusting, self-repairing, self-preserving, self-assertive, self-multiplying engine*. Even apart from intelligence and feeling, the body has an *esprit de corps*—an orchestrated purposiveness and individuality—which the formulae of chemistry and physics do not fit. Organism transcends mechanism.

No doubt, again, there is much that is automatic in our bodily life. How terrible it would be if we had to bend our minds to our breathing movements and to the beating of our heart! What a waste of time it would be if we had to learn to sneeze! Indeed, it has been part of the strategy of Organic Evolution to bring about inborn enregistrations which leave the organism free for higher adventures. Thus man has reflex actions, obligatory movements, or tropisms, instinctive predispositions, and so forth, to which he proceeds to add habituations and associations. How automatic such an achievement as riding a push-bicycle soon becomes! Yet the rider does not become a machine; even his most perfect co-ordinations are thrilled with consciousness. A man 's a man for a' that!

No doubt, again, there is a strong element of determinism in human life. 'An emmet may cry its heart out, but it will never make honey.' Yet what about the honey-ants! 'You cannot make a silk purse out of a sow's ear.' Yet what about the blind *Proteus* of the caves, that is able in the red light of the laboratory to develop a seeing eye? No doubt there are limits set by what is hereditarily bred in the bone,

imbued in the blood, and embodied in the mind, but few men rise to their hereditary limits. And we should not like to agree entirely with the distinguished expert who said the other day that neither the grindstone nor the oilstone of 'nurture' can make anything of the bad steel of inherited 'nature.' We can't all be born in Sheffield, and our alloy is neither all to the good nor all to the bad. Moreover the prevalent fashion of referring all our faults to our ancestors wears a bit thin. Our hormone system might have been more nicely adjusted, perhaps, but it is only in exceptional cases that a man can honestly say that he is a martyr to his ductless glands. Therefore, while admitting a factor of obligatoriness in the human constitution, we deny the machine.

There is a big little book, *Man Not a Machine* (in Kegan Paul's Psyche Miniature Series), by the late Eugenio Rignano, who was for years the distinguished and disinterested editor of *Scientia*, an international scientific journal of great merit. In this book the author gives nine reasons for *not* believing that he is a machine. Nine seems almost too many! The first is that no machine has the organism's power of always changing and yet remaining the same. The second is that no machine develops from an egg-cell as an organism does, nor can it mend itself as many a living creature can. Hardly less convincing is the third reason, that a living creature is from the first well adjusted to the conditions of its life. It shows pre-established adaptations, each more wonderful than another, and losing none of their wonder if we know their history, whether according to Darwin or according to Lamarck. How quickly an excess of carbon dioxide in the blood is put right, and equilibrium restored! Fourthly, the organism has what no machine shows, a considerable power of making entirely novel adjustments or adaptations.

Fifthly, even the simplest creatures have behaviour, a capacity for doing things and profiting by experience. They show 'mnemonic learning'—a phrase somewhat apt to be misunderstood; it means that they control their future by their past, which machines cannot do. Even reflexes and tropisms and instinctive promptings, which seem on the other side of our will and very obligatory, are purposive; and since it is a designer that puts purposiveness into a machine, a living creature cannot be a machine since there is no designer. So Rignano argues. The seventh argument is from animal appetites and desires, which machines have not got, but which become sublimed in man into the strong urge to expand and intensify his individual life. A machine has no wishes. The eighth argument emphasizes man's intelligence, and the ninth his social manifestations, such as morals.

We are reminded a little of the many reasons that a certain port gave for omitting to fire a salute in honour of a monarch who landed there,

the last reason being that they had no powder. So it seems to us almost unnecessary to go beyond the single reason that a machine could not make a theory that it is a machine. More interesting perhaps is the practical question how to become less and less of a machine. Part of the solution is paradoxical, but familiar to the biologist, ' by becoming more of one ' through the establishment of harmonious habituations which leave us with increased freedom of mind. But the major half of the solution is to do things which not even a calculating machine could begin to attempt. A man 's a man for a' that—but in a new sense!

Man's Greatness

The discoveries of modern science have confirmed the feeling of proud humility which led the Psalmist to say long ago: ' When I consider thy heavens, the work of thy fingers; the moon and the stars, which thou hast ordained; what is man, that thou art mindful of him? and the son of man, that thou visitest him? '

For we have had to learn to speak of the universe in the plural; our galactic system is only one out of many; our sun is not more than a mediocre star, compared, for instance, with Betelgeuse, within whose vast sphere the earth in its orbit could well revolve; our solar system is inconceivably far away from the hub of the system; and our earth is a minor planet. And was not a whirling nebula the gaseous pit whence we were digged, and the electronic rock whence we were hewn? We cannot but be overwhelmed with a sense of our insignificance. As an old thinker said: ' Man is a maggot and the son of man a worm.'

Yet we know that this salutary impression of man's insignificance amidst his environment has to be corrected by a conviction of his organismal greatness. For, after all, this reed shaken by the wind is a thinking reed, as Pascal said, and it is man who has been the measurer and interpreter of the world. It is man who has weighed the heavens in a balance and counted not only the hairs on his head but the chromosomes in the nuclei of his cells. It is in man that Nature has become articulate. In a very deep sense he is the maker and shaker of the world.

A frail creature, with feet of clay, shot through and through with weaknesses, easily bowled over by a bacillus, and yet great. As we have already said, man stands alone in having Reason, or the power of experimenting with general ideas, in having Language that expresses judgments, in controlling his conduct in the light of ideals, in being aware of his past and in being able in some measure to fashion his future, and in his power of building up outside himself a lasting social heritage which transcends the trammels of protoplasm. We

must judge every species by its best, and man at his best is great. Our question must change from 'What is Man?' to 'What is Man not?'

We think of it as a compliment that a great statesman or investigator, priest or poet, had a humble origin, but we have a somewhat snobbish dislike of being reminded of our own poor relations—the anthropoid apes. It is difficult to understand this repugnance, unless it be that we dislike to discern in ourselves the lingering traces of ancestral imperfections. After all, the divergence of hominoids from anthropoids occurred too long ago to bring a blush to our cheeks when we contemplate our nearest living relatives, like the gorilla; for the divergence must have occurred not less than a million years ago; and the Ascent of Man is greatly to his credit.

In any case the value of a hero is not affected by the fact that he was once a wayward child, and long before that an egg-cell of microscopic dimensions. Man's value depends on what he is and what he will be. And even as he is, solidary with the rest of creation, weighted with anachronisms and riddled with imperfections, how great are his qualities! Shakespeare saw man at his best, and that is the best way of regarding him. It is thus that we get nearest a discernment of his true inwardness.

The story of Organic Evolution includes retrogressions and eddies, but the big fact is advancement. As the hundreds of millions of years have passed life has been slowly creeping upwards, ever finding nobler and finer expression, associated throughout with a growing emancipation of mind. As Emerson put it, we see the worm, striving to be man, mount through all the spires of form. And while there is much to be said in praise of birds and bees, and the like, we cannot but regard man as the climax of the agelong progress. He has the greatest freedom of mind and the firmest mastery of fate. He is the most highly evolved living creature; he is not an episode, but the end that crowns the work. And just as we must consider man in the light of evolution, so we must envisage evolution in the light of man. For his uniqueness seems to give meaning to the long-drawn-out preface—to all the groaning and travailing of creation.

We remember, however, that many very remarkable animals, such as flying dragons, have had their day and ceased to be. Without leaving any direct descendants, they have passed from the stage with no more residue than a complication of the plot. Will this happen to man?

We remember also how our antecedent, though not direct ancestor, **Neanderthal Man,** was for a time the crown of creation, and yet was superseded by an upstart mutant who led on to *Homo sapiens*, that is to say, to us. Is there, perhaps, arising from our species a new

mutant that will rise as high above *Homo sapiens* as we have risen above *Homo neanderthalensis*? That possibility cannot be disproved.

Nor can we deny the possibility, suggested by the Bishop of Birmingham, that in the course of millions of years there may be a fresh start from a stock not even mammalian. Against the likelihood of that possibility it may be urged that the evolutionists of to-day think far less of the fortuitous factor in Organic Evolution than their fathers did in Darwin's day; that there has been in the evolution of Animate Nature something extraordinarily like a preparation for man; that it is difficult even to dream of the repeated emergence of a masterpiece as remarkable as man; and that a new super-organism would have little chance of survival in an environment which consists so largely of man's external heritage. As long as man does not stand still, he is not likely to be superseded.

CHAPTER III

THE HUMAN BODY. RACES OF MANKIND

Regions of the body—The skin—The muscular system—The skeleton—The skull—The teeth—The backbone—The arm—The shoulder-girdle—The leg—The hip-girdle—Uses of the skeleton—Joints—The nervous system—The brain—The sympathetic system—The sense-organs—The food-canal—The respiratory system—The vascular system—The heart hormone—The lymph—The thymus, spleen, and kidneys—The reproductive system—Man as a museum of vestigial relics—Races of mankind—Characters of human races—Classification of races.

THOUGH there are many differences between one human race and another, as between a Red Indian and a negro, most of these are on or near the surface, or else mental. There is great sameness in the general structure of the body, and most investigators agree that all the diverse races of mankind may be referred to one species.

REGIONS OF THE BODY.—In a horse or the like we distinguish at a glance between (*a*) head, (*b*) neck, (*c*) chest or thorax, (*d*) abdomen, and (*e*) tail; and so it is in man. But man's neck is relatively very short, as compared with a horse's (words fail us for a giraffe's), and relatively long, strange to say, as compared with a whale's, though the whale belongs to the same class, Mammalia. Moreover, the tail or caudal region disappears in man before birth, whereas it persists in the horse, and is a huge swimming-organ in the whale. But in many mammals, such as the bear, there is a marked reduction of the tail, and in the anthropoid apes it has disappeared. The general trunk of the body, between the fixing on of the fore-limbs and the hind-limbs, is divided into (1) the anterior thorax or chest region, supported by the ribs and breastbone, and enclosing the heart and lungs, and (2) the posterior abdomen, enclosing the stomach, intestine, liver, and other viscera. The abdomen has not a skeletal floor as the thorax has.

In ordinary quadrupedal mammals the heavy mass of organs enclosed in the abdominal cavity would tend to protrude downwards, but the organs are firmly slung to various parts of the skeleton, e.g. the backbone, and to the strong and partly muscular abdominal walls. In erect man the weight of the abdominal organs implies for the most part a downward and backward pull in a vertical direction, parallel and not at right angles to the backbone; the expanded hip-

girdle affords some support, but the various attachments are in a general way the same as in quadrupeds. The strain of hard work and the overgrowth of parts may cause **rupture** or **hernia** of the abdominal wall, followed by dangerous protrusion. This is almost unknown in Wild Nature.

When we grasp the dorsal part of a horse's neck below the origin of the mane, our fingers grip a strong hawser of connective tissue, called the *ligamentum nuchae,* which runs up to the back of the big head. It is attached to the neck region of the backbone, and has numerous strong muscles associated with it. Obviously enough, it serves for the attachment and movement of the head. If we put our fingers to the corresponding part of our own neck, we do not feel the great development of ligament and muscle that the horse shows in the same place; and part of the reason for the difference is that we stand erect with the weight of the head supported by our more or less vertical backbone.

THE SKIN.—In animals like lobsters and beetles the living skin is covered by a protective non-living cuticle, which is in no sense a tissue. The same may be said of the shell of an oyster, a snail, or a nautilus. But in backboned animals there is no cuticle in the true sense; the skin is exposed and is a true living tissue. Even if it be covered with scales, feathers, or hairs, these are composed of living cells as long as they are growing. Thus in ourselves the skin is on the surface, which seems a needless thing to say until we remember the many different kinds of backboneless animals, such as crustaceans and insects, where the true skin is covered by a cuticle.

The skin consists of the outer **epidermis** (badly called cuticle) and the deeper **dermis** or cutis. The epidermis includes two main strata, the outer horny and the inner Malpighian. It consists of various kinds of epithelial tissue, and it makes the glands and the hairs (see Fig. 264). It has no blood-vessels, as is familiar to those who shave, for no blood is drawn unless the edge of the razor slips below the epidermis into the dermis. The glands of the skin, though strictly ingrowths of the epidermis, are embedded in the dermis; and it is from this stratum that the growing hairs are nourished. In the epidermis are deposited the granules of pigment, of which we are more aware in the negro than in ourselves.

The dermis or cutis consists mainly of connective tissue, but there are some slowly contracting or smooth muscle-fibres. If we pull up the skin on the back of our hand behind the knuckles and then let it go, it at once sinks back into position. This is partly due to the elasticity of some of the connective tissue, but partly to the smooth muscle-fibres. In a fish, where the skin has not fully come to its own, the muscle-fibres are altogether below the dermis; but above

the fish-level the skin of backboned animals always includes some smooth muscle-fibres.

It should be noted (see DEVELOPMENT) that the epidermis is derived from the outer germinal layer or **ectoderm** of the embryo, whereas the dermis is due to the middle germinal layer or **mesoderm.** But in the development of scales, feathers, and hairs, the two layers co-operate intimately, the epidermis being the more formative, and the dermis the more nutritive.

As to the functions of the skin, it is protective, it is a sensitive layer, it helps in the regulation of the body-temperature, and it makes the oily secretion that lubricates the hair and the sweat-secretion which is partly a means of getting rid of water and waste-matter. Our skin can get rid of a very small quantity of carbon dioxide; it can absorb a little of some oily stuffs; and it makes pigment which may protect us from too much sunburn.

The wax-glands of the ear-passage are specialized sweat-glands, illustrating what has been a common method in Organic Evolution, viz., the derivation of a novel or specialized structure or function from another of a more generalized character and of earlier origin. But a better example is to be found in the **mammary** or **milk-glands**, which belong to the sweat-gland type.

The Muscular System

Whoever has eaten the well-cooked leg of a rabbit has noticed that the flesh or muscle falls into masses, each wrapped up in a thin connective-tissue sheath and connected at its two ends to two bones. These are typical muscles, each with a particular function of drawing two pieces of skeleton nearer one another. Each has got a particular name, often difficult to remember. But we all know the **biceps** of our arm, which is fastened at its lower end to the radius of the fore-arm, and at its upper end to the shoulder-blade, the fastening being due to **tendons** (or **sinews**) made of connective tissue. When we raise a cup of tea to our mouth we may use our left hand to feel the biceps becoming shorter and broader as it passes along the upper-arm bone or humerus. The biceps muscle bends the elbow-joint as we lift our cup; it pulls the fore-arm nearer the upper-arm; and this is the kind of work that *most* of our muscles do. As they work they become shorter and broader, a change that we can see as well as feel; and the contraction which is true of the muscle as a whole is true of each of the thousands of fibres that build it up. As we must not leave the tea-cup too long at our mouth, we straighten the arm again by using the **triceps** muscle on the humerus, which has its lower end inserted on the top of the ulna just above the elbow-joint.

But besides the separate muscles there are some *sheets* of muscular tissue like those in the wall of the abdomen or in the **diaphragm** or **midriff**, which runs across the body-cavity behind the chest. It is interesting to note that the early embryo may show, as in the face region, the division of a simple sheet into numerous special muscles. Every one has noticed a horse twitching the skin of its side to jerk off an irritating fly; and it does this by contracting a sheet of muscle that extends in many mammals under the entire skin of the trunk. Of this sheet, however, we have only what remains in the musculature of our face and part of the musculature of our neck. The facial part seems to correspond to the musculature of the gill-cover in bony fishes.

We have referred to special skeletal muscles, and to persistent muscular sheets, and we must not forget the musculature of hollow organs like the heart and the food-canal, whose contents are driven out by the contraction of the walls. The whole musculature of our body, along with the tendons, accounts for a large fraction of the total weight, say sixty pounds out of a total of one hundred and forty in an average white man five feet eight inches in height.

The muscle-fibres of the body are for the most part of the quickly contracting, cross-striped type, a common time for a single contraction being about one-tenth of a second. But slowly contracting muscle, consisting of smooth or non-striped spindle-shaped cells, is found in slow-moving parts of the body, notably the walls of the food-canal, the blood-vessels, the bladder, and the womb. As we have mentioned, small strands of smooth muscle run to the hairs on the skin, and may make them 'stand on end.' Smooth or plain muscle is also developed in the iris and ciliary processes of the eye, being used when we alter the size of the pupil and our focus. But the analogous musculature in a bird of prey, which has to descend like a bolt from the blue, is of the striated type.

Besides the striped muscle and the plain muscle, there is a special kind in the wall of the heart. The fibres in this hard-worked organ differ from ordinary striped fibres in having less distinct striations, no readily demonstrable sheath or sarcolemma, and a tendency to branch and unite sideways with their neighbours.

Ordinary striped muscle very soon becomes flabby and useless if its connection with the nervous system be broken; it is called voluntary. This is much less true of cardiac and plain muscle, which may retain for a time a certain degree of activity apart from innervation. In other words, they are more automatic.

It should be noted that muscles may be expending a good deal of energy though the body is not moving. Sir Arthur Keith remarks in his brilliant book, *The Engines of the Human Body* (1925), that if we swing our left leg forwards, we are using fifty-four muscles, but

the same number is being used by the stationary right leg, for the whole body has to be balanced on 'the round, slippery, and ball-shaped head of the right thigh-bone,' which fits into the equally smooth and slippery socket of the hip-bone. This balancing requires fifteen muscles, and if we take the whole of the stationary limb into consideration, the number of muscles concerned rises to fifty-four. 'Thus,' as Sir Arthur Keith says, 'in taking only a single step almost every one of the muscles or engines of the lower limbs—108 in number—are set agoing, not all at once, but in a definite and wonderfully regulated order.'

The subject is too difficult for us here, but we must notice the very important fact that even when a muscle is at rest, as in sleep, it is slightly on the stretch. This is called its **tonicity**, and for an ordinary striped muscle it is dependent on the connection with a nerve. A normal blood-supply is also essential.

The Skeleton

At first sight the skeleton of man, with over two hundred separate bones, seems very complicated, and one may, indeed, spend a long time in studying it; but its essential architecture, as in other mammals, is very simple. It consists of an axis and two pairs of appendages. The axis or **axial skeleton** is made up of the skull and the backbone; and, along with the latter, one may for convenience include the ribs and the breastbone. The bones of the appendages or limbs form the **appendicular skeleton**; and the fore-limb or arm is supported by the pectoral girdle, and the hind-limb or leg by the hip-girdle.

One of the famous diagrams in comparative anatomy is that in which Belon in 1555 drew side by side the skeleton of a bird and a man, naming with the same letters the bones which he regarded as fundamentally the same in the two types. Another famous figure shows the skeleton of a horse led along by the skeleton of a man, the corresponding bones in the two types being similarly lettered (see Fig. 440). Although the bird is a biped, and therefore with a skeleton more superficially like man's than is the skeleton of the quadrupedal horse, the differences are much greater in the first comparison, which was very daring for 1555. It may serve to emphasize our simple point that the skeleton in all backboned animals consists essentially of an axis and two pairs of appendages.

Another simple fact stands out clearly when we look at an ordinary mammal's skeleton (say a dog's) in its natural position and then at man's. The backbone of the trunk region of the dog's skeleton has been compared to a curved bridge with more or less vertical pillars or piers—the limbs—supporting each end. Beyond the top of the anterior and posterior pillars there is a projecting portion—anteriorly,

like a great crane, the neck and head, and posteriorly the tail, which is occasionally another lifting crane, as in some monkeys. To the more or less horizontal region of the bridge—the trunk skeleton—many structures are directly or indirectly attached, such as the food-canal, along which commodities pass. Along the upper part of the bridge (i.e. the vertebral column in the trunk region) there passes in a tunnel (the neural canal) a system of telegraph wires, the **spinal cord** or nerve-cord. But it is a remarkable bridge in this way, that it is movable from place to place, for the pillars or piers frequently detach themselves from the ground and move along to some other position, carrying the cranes and everything else with them! It may be that the actual skeletons are easier to understand than this whimsical comparison, but we merely wish to bring out the point that in man's case the posterior pillars (after the infant's hands-and-knees creeping) have lifted the whole bridge from the horizontal to the vertical, only lowering it on occasions, as when we allow the posterior pillar to bend down so as bring the anterior crane near the to ground to drink from a spring or enjoy a sweet violet. In short, in comparing man and ordinary mammal, we must keep in mind the difference between bipedal and quadrupedal.

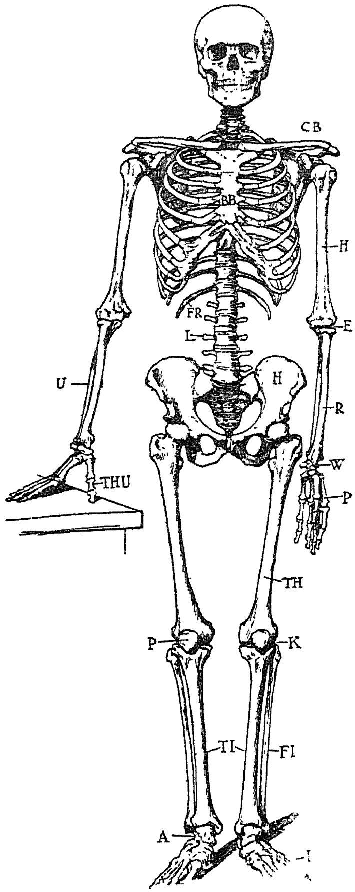


FIG. 442. THE HUMAN SKELETON

CB, collar-bone; BB, breast-bone; H, humerus; E, elbow; R, radius; U, ulna; W, wrist; P, phalange; THU, thumb; FR, floating rib; L, lumbar vertebra; H, hip; TH, thigh; P, patella (knee-cap); K, knee; TI, tibia; FI, fibula; A, ankle; I, instep.

In the evolution of Vertebrates, which has continued for hundreds of millions of years since Silurian Ages, skeletons of **gristle** or **cartilage** came before those of bone; and it is interesting to note that some of our bones, such as the thigh-bone and the occipitals of the skull, pass through a cartilage stage. Moreover cartilage lingers in a few places in our

skeleton, such as the lower parts of the ribs, extending from the bony upper part to the breastbone.

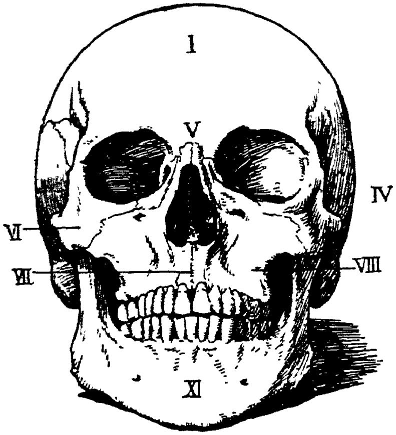


FIG. 443. HUMAN SKULL, SEEN FROM THE FRONT

I, forehead (frontal bone); IV, temporal region; V, interorbital region; VI, zygomatic bone; VII, intermaxillary suture; VIII, maxillary; XI, mandible.

THE SKULL.—What strikes one at first glance in comparing a man's skull with, say, a dog's, is (1) the relatively large size of the **cranial region**, which encloses the big brain. (2) Also notable is the practical absence of a snout or muzzle, for the **facial region** is more or less vertical. The paired frontal bones, which form part of the roof of the dog's skull, are approximately upright in man, giving him his fine forehead. (3) The sockets for the eyes, which are more or less to each side in ordinary mammals, are directed forwards in man; and this has to do with enabling him to see an object with both eyes at once, which makes binocular or stereoscopic vision possible. (4) The cheek-bones or **malars** are not strong in man, nor is their backward continuation to meet a forward extension of the **temporal** bones. This arch, technically called the **zygomatic arch,** is very strong in the dog, and relatively weak in man. The difference has to do with the fact that the arch affords attachment to some of the lower-jaw muscles which are used when the animal seizes its prey or carries it in its mouth, which we never do. (5) The top of the cranial region is formed partly from the paired **frontals** and partly from the paired **parietals.** Between the two parietals on the middle line in the dog's skull there is a longitudinal crest, called the **sagittal crest,** and to this there are attached some of the muscles which draw the lower jaw upwards. At right angles to the posterior end of this

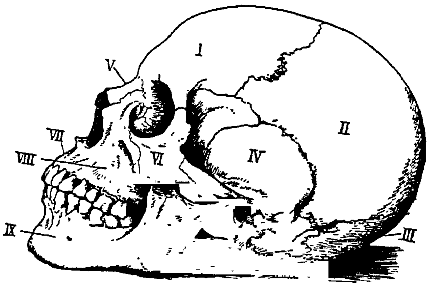


FIG. 444. HUMAN SKULL, SEEN FROM LEFT SIDE

I, frontal; II, parietal; III, occipital; IV, squamous part of temporal bone; V, nasal; VI, zygomatic; VII, intermaxillary suture; VIII, maxillary; IX, mandible.

sagittal crest in the dog's skull there is another called the **occipital crest,** the upper boundary of the hindmost or occipital region of the skull. To the posterior surface of the occipital crest are attached some muscles from the neck, whose contractions lift the head upwards. Man's skull does not show either of these two crests, and the reason is that they are not needed. Man is not in the habit of seizing things in his mouth or carrying them about in that way, and the muscles required for such functions are therefore but slightly developed. It may be noted that the temporal in man corresponds to the squamosal in ordinary mammals plus some adjacent bones fused on, e.g. the periotic which encloses the inner ear. With the squamosal or with the temporal, which comes to the same thing, the lower jaw or **mandible** articulates. There are eight bones in the cranial region and fourteen in the facial regions.

The line of junction or **suture** between two bones of the skull shows a remarkable appearance, as if the edges of two badly cut saws were fitted into one another, the teeth of the one into the notches of the other. It is comparable to dovetailing but much more complex; it gives great strength to the skull. In many mammals the sutures disappear in late life and two adjacent bones then become one.

If we turn a skull upside down we see a large aperture, the **foramen magnum,** through which the spinal cord or nerve-cord passes downwards from the brain. In ordinary mammals this hole is surrounded by four occipital bones (which fuse into one in man); and the lateral two are expanded to make two rounded knobs or **condyles** by which the skull works on the anterior end of the backbone.

Another important aperture is the ear-hole, leading into the inner ear—the true organ of hearing; and another, on the roof of the mouth, is the **posterior nostril** by which the in-breathed air, that is taken in by the anterior nostrils, passes into the back of the mouth. Numerous small holes in the skull allow nerves to come out from the brain.

THE TEETH.—Man's teeth form a continuous and graduated horseshoe-shaped series, and, as in other mammals, there is a milk set and a permanent set. The **milk teeth** begin to appear in the infant at about seven months and are added to till it is two years old, the total number being twenty, ten in each jaw. When the child is about six years old, the milk teeth begin to drop out and are replaced by the **permanent teeth,** thirty-two in number.

In most mammals there are three pairs of upper **incisors** carried by the premaxilla bone, and the same number below; but in man, as in apes and monkeys, there are only two pairs. Behind the incisors is the **canine tooth,** not so conspicuous as usual, and behind that are two **premolars** (or bicuspids, i.e. with two points) and three, more complex, **molars.** The premolars occur in two successive sets, but the

molars are not represented as calcified teeth in the milk set. The hindmost molars or **wisdom teeth** are the last to appear (from the seventeenth to the twenty-fifth year), and in some people they never cut the gum.

The upper incisors are carried by the premaxilla, and the others by the maxilla; but in man these two bones fuse. The **dental formula** is 2 *i*, 1 *c*, 2 *pm*, 3 *m* on each side above and below, 32 in all. Each tooth has a **crown** projecting above the gum, and **fangs** or roots embedded in a socket of the jaw.

THE BACKBONE.—This consists as usual of a succession of **vertebrae,** which correspond to segments or primary divisions of the young embryo. Each vertebra shows a substantial ventral (or anterior) 'body' or **centrum,** which works against its neighbours with the intervention of a gristly cushion at each end and strong strands of connective tissue, called **ligaments,** which run from bone to bone. In a typical vertebra the centrum bears a dorsal archway, which serves as a tunnel for the nerve-cord, and this **neural arch** ends in a backward or upward **neural spine.** On the arch there are, anteriorly and posteriorly, two **articular processes,** which link on to those of the adjacent vertebrae; and from the base of the arch there project two **transverse processes,** to which in the chest region the ribs are in part attached.

In the neck or **cervical** region there are seven vertebrae, and to this rule there are among mammals only four exceptions. The fact of blood-relationship in the whole class is shown by the fact that in the very short neck of a whale, with the vertebrae fused together, and in the extraordinarily long neck of the giraffe, there are the same seven vertebrae. A giraffe has been known to pluck *Acacia* leaves with its lips from a height of eighteen feet above the ground, and yet it has the same number of neck vertebrae as we have, namely seven. What has happened is a great elongation of the individual bones.

The first vertebra of the neck is called the **atlas,** and shows in front two concavities in which the knobs or condyles of the skull can work. When we nod our head and lift it again, or when we sway our head gently from side to side, we are moving our skull on the atlas. But when we rotate our head, looking backwards, to one side, we are moving the atlas on the second neck vertebra or **axis.** In almost every particular the atlas and the axis differ from one another, and it is a useful observational exercise to get clear specimens, e.g. of cat's or rabbit's backbone, and contrast the two, working out the reasons for their diversity.

Let us linger over this for a moment. The atlas has no centrum and no neural spine; the latter would be in the way when the skull was moved backwards or upwards. The axis has a strongly developed

centrum and a strong neural spine, but its transverse processes are not so strongly developed. In a rough way we may compare the atlas to a ring whose cavity is crossed by a strong ligament, dividing it into a larger cavity dorsally, containing the spinal cord, and a smaller one ventrally, into which there projects the strong **odontoid process** of the axis—a process which may be called the pivot when the skull is rotated. This process turns out to be the missing centrum of the atlas, which joins the axis in the course of development. All is adapted to ready, but safe, skull movements. When a mountaineer 'breaks his neck,' the instantaneous death is due to the odontoid process being jammed upwards against the spinal cord.

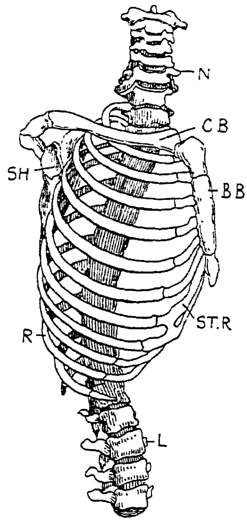


FIG. 445. SKELETON OF HUMAN THORAX

N, neck vertebrae; CB, collar-bone; BB, breastbone; ST.R, sternal portion of rib; L, lumbar vertebrae; R, rib; SH, shoulder-blade (scapula).

The next region of the backbone—the **thoracic** or **dorsal** region—consists of twelve vertebrae, and as many pairs of ribs. The first seven ribs are directly connected with the segmented **breastbone** or **sternum** by gristly 'sternal ribs,' which become partly calcified when we grow old, and thus lessen the elasticity of the chest-wall. This is a matter of some importance, for the raising of the ribs, more marked in women than in men, helps in breathing. The last two pairs of ribs, called 'floating ribs,' are not even indirectly connected with the breastbone. There is no difference in the number of ribs in the two sexes, but those of women tend to be more slender and more rounded.

The next spinal region, called **lumbar,** supporting the 'small of the back' or loins, includes five vertebrae, without ribs but with strong transverse processes. The next four, fused after early life, form the **sacrals,** and are firmly joined to the hip-girdle. At the end of the sacrum are four small vertebrae fused to form the **coccyx,** which corresponds to a tail, but does not project.

THE ARM.—The skeleton of the fore-limb is made up of:

the *humerus* of the upper arm;
the inner *radius* and outer *ulna* of the lower arm;
two rows of *carpal* or *wrist-bones,* four in each row;
five *palm-bones* or *metacarpals*;
five *digits,* each with three joints or *phalanges,* except the *thumb* (*pollex*), which has only two.

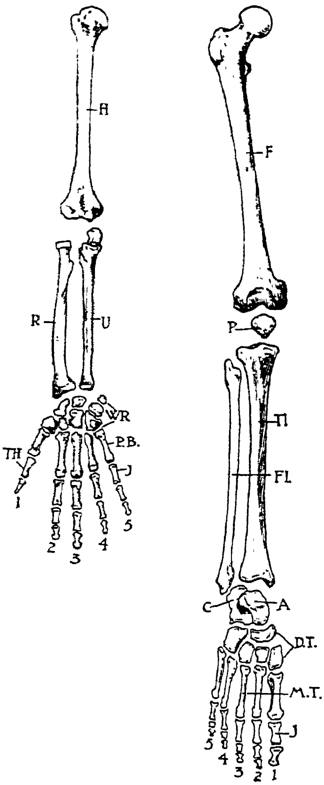


FIG. 446. SKELETON OF HUMAN ARM (left) AND LEG (right).

Arm composed of: H, humerus; R, radius; U, ulna; WR, wrist; PB, bones in palm of the hand; TH, first joint of thumb; J, first joint of little finger; 1–5, five digits of the hand.

Leg composed of: F, femur; P, patella or knee; TI, tibia; FI, fibula; C, calcaneum, forming the heel; A, astragalus; DT, distal tarsals or ankle-bones; MT, metatarsals; J, first joint of the hallux or big toe; 1–5, five toes of the foot.

When we rest our left arm on the table, holding an open book up to our eyes, we are pressing on a large upper process of the ulna which projects beyond the elbow-joint; it is called the **olecranon** or elbow process. The radius can roll half-way round the ulna, thereby bringing the hand palm up (supination) or palm down (pronation).

Some children are born with only two joints or phalanges in their fingers. This variation, known technically as **brachydactylism**, is sometimes spoken of as 'having the fingers all thumbs,' for a normal thumb has only two joints. It is very apt to be handed on as part of the inheritance, and has been known to recur in five generations.[1] Occasionally there is an extra finger, **polydactylism**, another freak.

Developed in skin pockets, from the outermost layer of the epidermis, are the horny **nails**, which correspond to the claws of carnivores and the hoofs of ungulates, though the mode of development is different in detail.

We cannot pass from man's hand without emphasizing what we have noticed in another section, that its skeleton is very *generalized*, as compared, for instance, with that in many other mammals, such as bat, aye-aye, horse, and mole, where it is much *specialized*. For a nimble-witted creature like man it is a great advantage to have a hand that can do a hundred different things with equal efficiency.

THE SHOULDER-GIRDLE.—The broad upper end of the humerus: works in a polished hollow on the shoulder-blade or **scapula**. This big movable bone lies on the dorsal surface of the thorax, and is

[1] It behaves as a Mendelian recessive character (p. 987).

moored by muscles to the backbone. These and others from the arm are fastened to a strong ridge or *spine* on the scapula, and the free end of this spine is fastened by fibrous tissue to the outer end of the collar-bone or **clavicle,** which runs across from the top of the breastbone. This collar-bone, which we can feel so easily with our fingers, corresponds to the familiar 'merrythought' in birds; it is the bone that is often broken in a bad tumble, as in football. But the scapula has another process, called the **coracoid process,** which is a strong separate bone in the two lowest mammals, as well as in birds and some reptiles. It is separate in the human embryo, and is thus one of the tell-tale bones that throw light on remote history—when mammals sprang from an extinct (*Cynodont*) stock of reptiles.

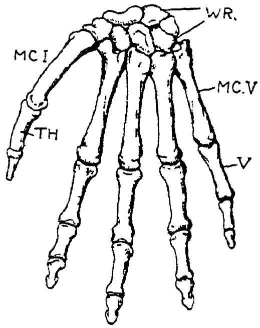


FIG. 447. SKELETON OF HUMAN HAND

WR, wrist; MC.I, first metacarpal; TH, first joint or phalanx of the thumb; MC.V, fifth metacarpal; V, first joint or phalanx of the little finger.

THE LEG.—The skeleton of the leg consists of the following bones:

- the *thigh-bone* or *femur,* above the knee;
- below the knee, the inner *tibia* or *shin-bone,* and the outer *fibula*;
- the *upper tarsal* or *ankle-bones, astragalus* and *os calcis*;
- the *lower tarsals,* five in number;
- the five *sole-bones* or *metatarsals*;
- the *toes,* with three joints or *phalanges,* except the *big toe* (*hallux*), which has only two.

When we stand on one foot, we are balancing our whole body on the slippery globular head of the thigh-bone, which fits into a slippery socket of the hip-girdle (Fig. 448). One can hardly be surprised that the 'head' sometimes slips out—in dislocation of the hip-joint.

The knee-joint is between the lower end of the femur and the upper end of the tibia. In front of this, within a big tendon, there lies the knee-cap or **patella**—the largest example of those bones that develop apart from the ordinary endoskeleton, in connection with tendons at joints, and are called **sesamoid bones.**

The tibia is much stronger than its neighbour the fibula, and it has to bear almost the whole weight of the body. Its lower end works against the **astragalus**—one of the two upper ankle or **tarsal** bones. Beside this lies the **heel-bone** or *os calcis,* a strong bone projecting backwards. It forms the hind pier of the arch or **instep** of the foot, the astragalus being the keystone, and the balls of the toes the anterior piers. This arch-like arrangement gives the foot great strength, and

one can understand that in oldish people, who are getting tired, the arch, which is supported by *muscles, tendons,* and *ligaments,* is apt to give way, the result being *acquired 'flat-foot.'*

The femur corresponds to the humerus; the tibia and the fibula correspond to the radius and the ulna respectively; the tarsals to the carpals; the metatarsals to the metacarpals; the toes to the fingers —the same parts turned to very different shape and use. But the foot of man is much *specialized,* as compared with the generalized hand. In the abnormality known as *club-foot,* when the soles are turned inwards towards one another and the child walks partly on the outer border of the foot, there seems to be a return or reversion towards the normal ape type.

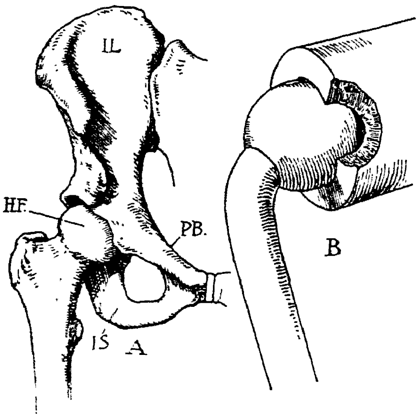


FIG. 448. THE HIP-JOINT, SHOWN IN DIAGRAM A, WHICH WORKS AS A SIMPLE BALL-AND-SOCKET JOINT, SHOWN IN DIAGRAM B

IL, ilium; HF, head of femur or thigh-bone; PB, pubis; IS, ischium.

THE HIP-GIRDLE.—The fused sacral vertebrae give attachment on each side to a strangely shaped bone, which was contradictorily called 'the unnamed bone' or *os innominatum.* It is formed by a fusion of the three bones which typically make up a **pelvic girdle** or hip-girdle, namely, the *ilium,* the *ischium,* and the *pubis.* By far the largest is the ilium, which extends backwards and upwards and is attached internally to the sacrum. Running dorsally, but posteriorly, is the much smaller ischium, and when we sit down timidly on the edge of a chair, we are supporting our body on the outer margins of the two ischia. A third bone—the pubis—runs across ventrally in front of the ischium, and unites with its fellow from the other side to form the **pubic symphysis.** These three bones, ilium, ischium, and pubis, all contribute to make the deep cup or **acetabulum** in which the globular head of the femur works. This is the case in all Vertebrates that have a hip-girdle.

Anteriorly the bones of the pelvic girdle form between them a widely open basin, which is useful in affording some support to the lower intestine and to adjacent organs. When the offspring is about to be born, it passes from the womb or uterus outwards, through the wide, ventrally open, gateway of the pelvis.

There are several pieces of the skeleton that we have not mentioned, and two of these are of special interest. At the root of the tongue is the **hyoid** bone, bound by muscle and ligament to the skull, affording insertion to some tongue-muscles, and also serving for the support of the adjacent larynx or voice-box, which has, as we shall notice, a complex skeleton of its own. Now this hyoid corresponds to part of the hyoid arch of fishes, where it helps in making the skeleton of the anterior region of the gills, e.g. the support of the gill-cover rays, if these are developed. But to the hyoid proper, at levels above fishes, there are tacked on the transformed remnants of the first, two gill-arches or **branchial arches**, bearing their old name even when they cease—in reptiles, birds, and mammals—to have gills associated with them.

Even more dramatic in their historical significance are three little bones in connection with the inner ear. They form a three-link chain between the drum or **tympanum**, which runs across the ear-passage, and a window into the inner ear, the true organ of hearing, lodged in the inner recesses of the temporal bone. In ordinary mammals this inner ear lies in a separate bone, the periotic, which forms part of the human temporal. The three ear-bones or ear-ossicles are named from without inwards: (1) the *malleus* or hammer (pressed against the drum), (2) the *incus* or anvil, and (3) the *stapes* or stirrup, applied to the window or **fenestra** into the inner ear. They serve to convey to the hearing organ proper the vibrations produced on the tympanum by outside sound-waves. A study of their development goes to show that the malleus corresponds to the articular of the lower jaw of a reptile; the incus to the quadrate; and the stapes to the columella (part of the hyomandibular of a fish like the cod). While there is some legitimate difference of opinion in regard to these correspondences or **homologies,** there is no doubt that the delicate three-link chain of ear-ossicles in mammals is derived from pieces of skeleton that were originally parts of the commonplace framework of the jaws. In amphibians, reptiles, and birds, the place of the three-link chain is taken by a single rod—the **columella,** which is very easily seen in a frog.

USES OF THE SKELETON.—The answer to this question is not quite so obvious as it might at first appear. (1) A jellyfish may be larger and heavier than a man, yet it has no trace of a skeleton. This is to be thought of in connection with the fact that the body of the jellyfish is entirely supported by the water, it has no need for a *supporting* skeleton. But in Vertebrate animals this is needed as a framework to which to attach most of the muscles, and, more or less directly, a diversity of organs. (2) In terrestrial Vertebrates part of the skeleton is used to form *levers* for working against a firm substratum. The same utility is well illustrated by many arthropods, such as the crab

on the seashore or the beetle hurrying across the path, but in this group of animals, as we have explained, the skeleton is mostly an **exoskeleton,** made of a non-living cuticle of chitin, and with the muscles of the limbs inside their support. In Vertebrates, however, the skeleton is mostly an **endoskeleton,** made of living bone, and with the muscles fastened to the outside surface of their support. This is a good illustration of two very different solutions of the same practical problem. (3) A third use of the skeleton is to *protect*; thus our skull protects not only the brain, but the essential parts of the eye and the ear. (4) Perhaps we may recognize a fourth utility, that the skeleton helps to make the body more of a unity—so that it can act as an integrated whole. This is conspicuously the case in a reptile like the tortoise, which is surrounded by unified armour, and in the quaint armadillo, which stands alone among living mammals in having a strong encasement of skin-bones (**dermal scutes**). But even in naked man the skeleton integrates the body.

JOINTS.—If we define a ' joint ' as the region of movement between two bones that work on one another, we must recognize over two hundred joints in the human body. They work extraordinarily well, lubricating the surfaces that work on one another and providing against wear and tear. What do we find where the humerus works in the **glenoid cavity** of the shoulder-blade, or the thigh-bone in the **acetabulum** socket of the hip-girdle, or the tibia of the lower leg against the **astragalus** of the ankle, or in any typical joint? The opposed ends of the two bones that work on one another are covered with a thin plate of cartilage, built up of cartilage-making cells which continually replace those that get worn away. The débris at the moving surfaces forms a lubricating oil, the **synovia,** which reduces friction to a minimum and gets drained away into the blood-stream when it begins to lose its freshness. Then there are the tough **ligaments** which run from one bone-end to the other. No joint in a machine is so finely adjusted as a typical joint in man. There are, of course, different degrees of perfection, and there are different types—e.g. (1) the ball-and-socket type, like the head of the thigh-bone in the hip-girdle socket; (2) the hinge type, like the elbow and the knee; and (3) the pivot type, between the first and second vertebrae. [See Sir Arthur Keith's *Engines of the Human Body* (1925), and his *Human Body* (Home University Library).]

The Nervous System

The nervous system includes the brain, the spinal cord, the nerves that issue from these, and the sympathetic system. The sense-organs must also be reckoned as practically inseparable from the nerve-centres and ganglia to which they send in tidings. The whole system consists

of nerve-cells and their outgrowing fibres, each unit being called a **neuron.**

THE BRAIN.—This great mass of nervous tissue, weighing about three pounds in an average-sized man, is sheltered by the cranial part of the skull. It is the centre of the central nervous system and the home of thought, feeling, and purpose. To us nowadays it seems almost incredible that Aristotle, whose brain must have been one of the very finest, did not know the use of the organ, but thought it had something to do with the cooling of the blood!

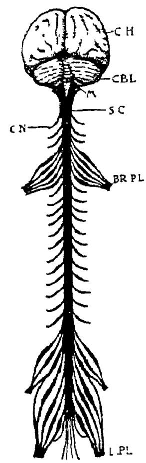


FIG. 449. HUMAN BRAIN AND SPINAL CORD

CH, cerebral hemispheres; CBL, cerebellum; M, medulla oblongata; SC, spinal cord; CN, cranial nerves; BR.PL, brachial plexus; L.PL, lumbar plexus.

As in other Vertebrates, there are five main regions in our brain.

(1) Largest, foremost, and hiding all the rest, is the **cerebrum** or **fore-brain,** with numerous convolutions. Because of its shape it often gets the name of cerebral hemispheres, and the two halves are separated by a deep cleft, across the bottom of which there runs a transverse bridge of fibres—the **corpus callosum**—which makes the cerebrum more of a unity. Another bridge, running longitudinally from the anterior to the posterior parts of the cerebral hemispheres, is called the **fornix.** The anatomist calls the base of each hemisphere, where great strands (*peduncles*) enter from behind, the **basal ganglia,** while the convoluted upper region is called the **cortex**; both are made up of hundreds of thousands of branching nerve-cells, the **grey matter,** while the mass of tissue between cortex and basal ganglia is composed of nerve-fibres, which transmit messages, and is known as the **white matter.** The cortex is a thin layer (1·5–5 mm.), but much more extensive than it appears to be, for it is much folded upon itself, forming the convolutions, and is the seat of the higher mental processes. By counting the neurons in a microscopic section of a minute fraction of the cerebral cortex of man, it has been found possible to make an estimate of the total number. One of the most reliable of these estimates gives the total at 9,200,000,000, about five times the number of people living at present on the earth. Yet all this multitude of neurons, if well packed without blood-vessels and supporting tissue, would go into a cubic inch, and weigh no more than about thirteen grammes. This fact is enough to convince us that size and weight do not count for very much, for this cubic inch is *the home of our mind* which measures the universe.

The cerebral cortex was an acquisition made by mammals in the early ages of their evolution, and is therefore called by Sir G. Elliot Smith the **neopallium.** But it came to its own in the series beginning with the tree-shrew and ending (for the time being) in *Homo sapiens*. If we compare the fore-brains of dog and rabbit we see at once that the dog has many convolutions and the rabbit no more than a hint of any. This suggests the rough generalization that the cleverer mammals have the most intricately convoluted brains; but it is also necessary to take account of the ratio between brain-size and body-size. Some small mammals with almost smooth brains are as clever as they need to be, and this is partly due to the fact that their brains are big for the size of their body. The cerebrum, like the brain in general and the spinal cord as well, is surrounded by three membranes —the hard outermost *dura mater*, the vascular innermost *pia mater*, and a delicate *arachnoid* between them.

(2) Below the corpus callosum and behind those basal ganglia which are called the corpora striata, there are other basal ganglia forming the **optic thalami**, the second region of every Vertebrate brain. They are sometimes given the name of inter-brain or 'tween-brain, and though small in size they are of great interest. They probably serve to transmit impressions of touch from the body to the cerebral hemispheres, but they are of even greater importance because of what they originate. (*a*) In the embryo they give rise on each side to an outgrowth which forms the beginning of the eye. (*b*) On the roof they give rise to the **pineal body**, which has the appearance of being a median eye in the New Zealand lizard (*Sphenodon*). In man, however, the pineal body seems to produce an **internal secretion** or **hormone**, which passes, as is usual in the product of ductless glands, into the blood. (*c*) On the brain-floor the region of the optic thalami gives rise to the major part of the **pituitary body**, another part being due to an upgrowth from the roof of the mouth. The pituitary body is partly nervous and partly glandular. Its anterior portion produces a hormone which influences the growth of the body and the sexual development. If it is over-active, the result may be a giant; when it is relatively inactive, the result may be a stupid 'fat boy.' The posterior part of the pituitary body is also a hormone-producer, and its secretion, distributed by the blood, has to do with the metabolism (q.v.) of sugar and fat, and also with the activity of the smooth muscle-fibres. An extract from the posterior portion is now used in medicine to raise the blood-pressure.

(3) Behind the optic thalami are two pairs of small basal ganglia, the fourfold bodies or **corpora quadrigemina**, which are twofold bodies (*corpora bigemina*) in Vertebrates lower in the scale than mammals. They form the roof of the mid-brain, whose floor consists of fibrous

masses, the **crura cerebri**, which connect the cerebral hemispheres with the front end of the spinal cord.

(4) Overlapped by the cerebrum is the large **cerebellum** (the 'small brain'), which occupies the lower part of the cranial cavity. It is also divided into two hemispheres, and its cortex is folded or convoluted in a peculiar pattern, a slice showing an oak-leaf pattern, which the ancients named the *arbor vitae*. A cross-bridge of fibres below the posterior part of the cerebellum is called the **pons.** The cerebellum and the pons taken together form the **hind-brain**; and the cerebellum has for its particular function the control of the balancing movements. It must be understood that these parts are all linked together: thus the cerebellum gives off half a dozen strands of nerve-fibres, which establish interconnections, and are called peduncles or crura.

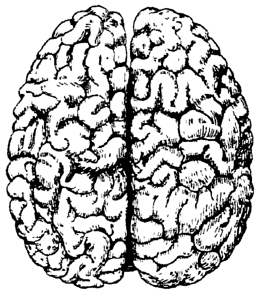


FIG. 450. THE CEREBRUM

(5) The hindmost part of the brain, giving off more nerves than all the rest taken together, is the **medulla oblongata,** or bulb, or after-brain. It carries forwards some of the nerve-fibres from the spinal cord, into which it passes posteriorly. It is a very important reflex centre in connection with the heart, the breathing-organs, and the like. Twelve pairs of nerves (**cranial nerves**) are given off from the brain as a whole, some (*a*) sensory, carrying tidings inwards, like the optic from the eye; others (*b*) motor, carrying commands outwards, like the oculomotor to one of the six muscles moving the eye; and others (*c*) 'mixed,' with fibres of both kinds, e.g. the trigeminal to the mouth region, which informs us of toothache with some of its *sensory* fibres, and commands chewing with some of its *motor* fibres.

The central nervous system begins in the embryo as a streak of ectoderm cells along the dorsal median line. Through inequalities of growth this becomes an open groove (the **neural** or **medullary groove**), and this in turn a canal (the **neural or medullary canal**). This becomes in the spinal cord a small ciliated **cerebro-spinal canal,** and in the anterior expansion which develops into the brain it forms the cavities or **ventricles.** These contain a fluid like that in the spinal-cord canal, and in the disease called 'water on the brain' this fluid is abnormally large in amount and the ventricles are correspondingly expanded.

THE SPINAL CORD.—Well protected within the tunnel formed by the neural arches of the backbone lies the spinal cord, which passes anteriorly into the medulla oblongata of the brain. It is a bilateral structure, fifteen to eighteen inches long, about the thickness of our

little finger, and gives off thirty-one pairs of **spinal nerves**. Each nerve has two roots: (1) a *dorsal, posterior, afferent*, or *sensory*, which carries tidings inwards to the spinal ganglia and thence into the cord; and (2) a *ventral, anterior, efferent*, or *motor*, which carries commands outwards to the muscles and glands. The two roots combine as they leave the cord, so that one nerve is formed, inside a common sheath, but the component fibres, which lie side by side, retain their respective sensory and motor function—a great discovery made by Sir Charles Bell (1774–1842). The spinal cord consists of an H-shaped column of grey matter (branching nerve-cells), surrounded by white matter (nerve-fibres). It is the great conductor of nerve-impulses from the brain downwards and to the brain upwards; and it is also a great centre for **reflex actions** (q.v.).

THE SYMPATHETIC SYSTEM.—On each side of the backbone, near the origin of the spinal nerves, there is a chain of twenty-four to twenty-five small **sympathetic ganglia.** They are outliers of the spinal cord, but not to be confused with the **spinal ganglia** on the dorsal roots and also outside of the cord. The sympathetic ganglia are connected by nerve-fibres (*a*) with one another, (*b*) with the ventral roots, and (*c*) with adjacent blood-vessels and organs. They have to do with the automatic regulation of these, and are sometimes called **autonomic.** The significance of the sympathetic system is not as yet fully understood, but perhaps it is safe to say that it is outside the control of our will and very much within the influence of our emotions. When our face pales with fear or flushes with joy, the blood-vessels are reacting to messages which have *passed through* the sympathetic ganglia.

The Sense-organs

In a simple animal like a sea-anemone there is no brain nor nerve-centre of any kind, but there are numerous neurons diffusely distributed. Some of these are **sensory cells** or **receptors** which are susceptible to outside stimuli. But they are not like our eyes in gathering impressions from the outside world; they are simply the triggers which activate muscles. This was the use of sensory cells and sensory organs before they began to collect information from the outer world. A central nervous system is necessary if the sense-organs are to serve as gateways of knowledge.

THE EYE.—It is easy to get a couple of ox-eyes from the butcher, and to see much by using a sharp knife or razor to make cuts in various planes. The manipulation is easier when the eyes have been soaked for a week or so in strong methylated spirit.

Our eye is protected in the bony **orbit,** partly roofed by the frontal bone. It is packed round with fat, and moved by six muscles. As

we find the same six muscles in a codfish and all through the Vertebrates above that level, we get a good instance of unity of structure over a wide range; and in a general way the same is true of the eye itself.

The eye may be compared to a globular camera. The sensitive plate is the innermost layer or **retina,** innervated by branches of the optic nerve from the brain. Occupying the front of the globe is the biconvex **lens.** This lies in an aperture, the **pupil,** and is surrounded in front by the pigmented and muscular **iris.** The curvature of the lens is altered by 'ciliary muscles.' These start in a circle from the hard fibrous wall of the eyeball—the **sclerotic,** where it joins the iris in front. The lens is also moored by 'ciliary processes' which spring from the **choroid**—the black and vascular layer between the sclerotic to the outside and the retina to the inside. The lens is protected in front by a firm **cornea,** continued on from the sclerotic, and the cornea is covered externally by a delicate **conjunctiva,** which is continued on to the inner surface of the eyelids. Between the cornea and the iris is the 'anterior chamber' of the eye, a lymph space containing a clear fluid—the **aqueous humour.** The main cavity of the eye, behind the lens, is filled with a clear jelly—the **vitreous humour.** It will be understood that the wall of the camera consists of the external protective sclerotic, the inner image-forming retina, and between them the black choroid with many blood-vessels.

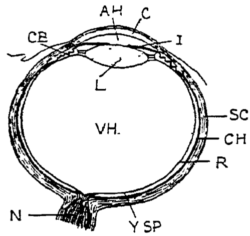


FIG. 451. SECTION OF HUMAN EYE (DIAGRAMMATIC)

C, cornea; AH, aqueous humour; CB, ciliary body; I, iris; L, lens; SC, sclerotic; CH, choroid; R, retina; VH, vitreous humour; Y.SP, yellow spot; N, optic nerve.

The retina is an exceedingly complex structure with thousands of cells in over half a dozen layers, partly supporting and partly nervous. Nearest the lens is the nervous layer where the optic nerve gives off numerous fine branches. But furthest from the lens and next the choroid is the layer of the **rods and cones,** which are the sensitive elements. The place where the optic nerve enters the back of the eye is called the **blind spot,** where there is no vision. A little to one side of this is the yellow spot, the area of acutest vision, where the layers of the retina have almost entirely thinned off except that of the rods and cones, the latter greatly outnumbering the former.

In development the retina is directly derived from the back wall of an ectodermic optic club that grows out on each side from the brain; the lens is directly derived from the epidermis; the rest is mesodermic.

THE EAR.—Many backboneless animals have an 'ear,' but it is

usually a receptor for vibrations or else a **balancing-organ.** In back-boned animals from Amphibians to Mammals there has been added the very important, yet secondary, function of **hearing.** The Vertebrate ear is a receptor for the oscillations of an internal fluid or the vibrations of particles suspended in its cavity, but it is also a receptor for sound-waves.

The external ear-trumpet or **pinna** collects the waves of sound, and, when we move our head about, it helps in their location. We see a waiting horse moving its ear-pinna without moving its head, but we have to move our head when we try to determine the direction from which the sounds are coming. The small muscles in our pinna are merely vestigial, though they can be activated in a small percentage of cases. It is interesting to notice that some of those variants (or freaks) have also an unusual power of moving other parts that are usually at rest, such as the scalp and the nose.

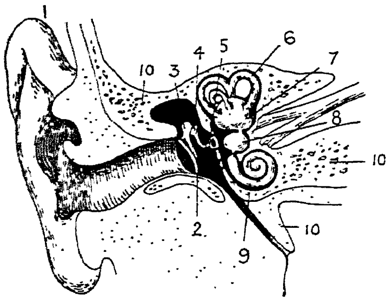


FIG. 452. DIAGRAM SHOWING STRUCTURE OF HUMAN EAR

1, external ear-flap or auricula; 2, tympanum or ear-drum; 3, malleus; 4, incus; 5, stapes; 6, semicircular canals; 7, utriculus; 8, sacculus; 9, cochlea; 10, bones of skull enclosing ear.

The external ear-passage has wax and hairs, both helping to arrest dust-particles; and across it at its inner boundary there runs the **drum** or **tympanum,** which lies flush with the skin in the frog, as also in the human embryo and in the new-born American monkey. The in-sinking to a more protected position is secondary. From the quivering drum the vibrations pass (through the middle ear) by a three-linked chain of ossicles, already referred to—an outermost malleus, a median incus, and an innermost stapes. The last abuts on the **fenestra ovalis,** a minute membrane-covered aperture in the wall of the 'bony labyrinth' enclosing the inner ear, the true organ of hearing.

The 'auditory vesicle,' which forms the inner ear, began in the embryo, and doubtless in the race also, as a simple sac; but its adult structure is very complicated, and we can only refer to the essential parts. The sac is divided into two chambers, a larger utriculus and a smaller sacculus. The **utriculus** gives off three semicircular canals, curved tubes with bulgings or **ampullae** at their bases; and these have mainly to do with the balancing function.

From the smaller sac—the **sacculus**—there is given off a spirally coiled tube, the **cochlea,** which is believed to be the most essential

part of the ear as far as the perception of sounds is concerned. It includes a very remarkable structure called the **organ of Corti,** which almost baffles description. It consists in part of a series of about 3,000 arch-like fibres, which carry auditory cells with stiff hair-like processes or cilia. These are innervated by the fine endings of the **auditory nerve,** by which messages pass to the brain. Corti's fibres suggest the keyboard of a piano and it is believed by some physiologists that each hair is sensitive to a particular kind of vibration.

It should be understood that utricle, semicircular canals, saccule, and cochlea form a continuous **membranous labyrinth,** and that outside this there is a corresponding **bony labyrinth,** with a little fluid between them. The membranous labyrinth is lined by delicate epithelial cells and contains a fluid—the **endolymph.** In the sac of the utricle there are minute crystals (*otoliths*) of calcium carbonate, suspended in the fluid, and perhaps jostling against the hair-cells when the fluid oscillates.

Let us suppose that someone claps his hands; sound-waves are produced in the air; some of these are collected by the ear-trumpet and led down the outer ear-passage; they impinge on the drum; the vibrations of the drum are transmitted inwards by the chain of minute ossicles; the membrane of the window into the inner ear is influenced; the endolymph fluid oscillates; the hair-cells receive the tidings; the auditory nerve carries a message to the brain; and *we hear* our friend clapping his hands.

One must not forget the **Eustachian tube,** about an inch and a half long, which leads from the middle ear (or drum-cavity) to the back of the mouth, and is the only open communication between the middle ear and the outer world.

SMELL.—In all probability the sense of smell was more vitally important to man long ago than it is to-day. We know that it is of survival value to animals like carnivores, for they would soon come to an end if they could not scent their prey, but this is not true of man. There is no convincing reason for the belief that the human sense of smell is undergoing *racial* degeneration, but there is no doubt as to its dullness in individuals. This may be due to the prevalence of strong odours like those of tobacco smoke and petrol, or to the careless tolerance of 'colds in the head,' or to our indifference in regard to a sense that is not a gateway of knowledge in the same degree as sight and hearing. Yet the widespread dullness to smell is to be regretted, since it leads to an undesirable tolerance of stuffy rooms, bad food, and lack of freshness generally. There does not seem to be anything wrong with our smelling organs.

From our nostrils (**anterior nares**) there is a passage to the posterior nostrils (**posterior nares**) at the back of the mouth; and through this

passage the air used in breathing moves in and out. But, as we are well aware, our nasal passage has also a smelling function. Into it there project delicate scroll-like bones (the **turbinals**), and the whole cavity is lined by a delicate membrane, partly glandular and partly ciliated and sensitive. As the air passes in it is warmed, and the nasal secretion is believed to kill microbes and to catch some of the dust. But among the sensitive cells of the lining membrane of the nasal cavity there are some that are specialized for odours only. They are congregated on a square **smelling-patch**, about one-tenth of an inch to each side, situated on the uppermost scroll-fold and on the partition between the two nasal chambers. These smelling-patches differ in number in different mammals, rising to ten in the nocturnal aard-vark of South Africa, and practically disappearing in the toothed whales.

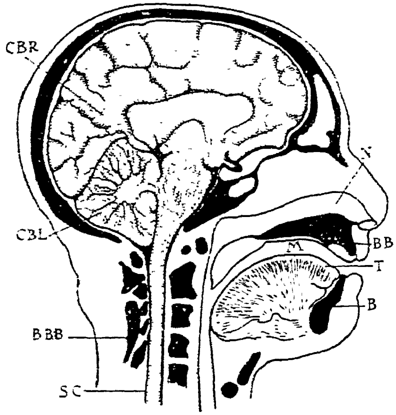


FIG. 453. SECTION THROUGH HUMAN HEAD

N, nasal passage; BB, top jaw-bone; T, tongue; M, mouth; B, lower jaw-bone; SC, spinal cord; BBB, bones of vertebral column; CBL, cerebellum; CBR, cerebrum.

The nerve-endings on our smelling-patches arise (*a*) partly from branches of the first or **olfactory nerve,** receptive to delicate flavours, and (*b*) partly from branches of the fifth or **trigeminal nerve,** receptive to irritants. Tobacco smoke is said to affect both kinds at once. In any case, though we say that we detect a smell from a distance, there is no stimulation unless actual particles (vaporous or gaseous), carried through the air, come into *contact* with the smelling-patch, probably in some sort of solution. When we deliberately sniff to locate an escape of gas or the like, we are forcefully drawing in a sample of air so that it may not pass through the nasal chamber without striking a smelling-patch. It is said that an acute nose can detect one thirty-millionth part of a grain of musk.

The dulling of taste when we have a heavy 'cold in the head' may be due to a blocking of the upper part of the nostril, or to a smothering of the olfactory endings with profuse secretion, for much of what we call taste is really smell. But to some strong odours, e.g. oil of lemon and ionone (synthetic violet oil), the smell-patches soon become fatigued, even when everything is otherwise normal.

TASTE.—When we taste anything, pleasant or unpleasant, there is a stimulation of groups of cells called **taste-buds,** most of which are situated on the back part of our tongue. A taste-bud consists of elongated cells, each ending in a hair-like process, which is irritated by contact with dissolved substances. In technical language, taste is *a contact chemical receptor*; we cannot taste from a distance. We have many hundreds of these taste-buds, and they may occur away from the tongue, e.g. on the soft palate or on the **epiglottis** (q.v.). They are more widely distributed in children than in adults, and some fishes have them outside of the mouth altogether. When man was feeling his way in the world, the sense of taste was probably more important than it is now, for it prevented the experimenter from being poisoned. A nauseating taste implies a message to the brain and an answer comes back in a fraction of a second (often about one-sixth), and the muscles to which the command comes are thus stimulated to reject the food. But pleasant tastes favour the secretion of digestive juices. The four fundamental tastes are sour, salt, sweet, and bitter.

TOUCH.—All over our skin, but more abundantly on strategic places like the finger-tips, there are **touch bodies.** They lie in papillae of the under-skin or dermis, and each is a minute oval corpuscle, into which a nerve-fibre enters, usually after winding round and round. Sometimes the termination of a tactile nerve-fibre is simply a naked branching in the deeper layer of the epidermis; and there are other ways of ending. Our skin is sensitive not only to contact, but to pressure, to heat and cold, and to burning chemicals; but each kind of nerve-ending or receptor is sensitive to one kind of stimulus.

HOW MANY SENSES HAVE WE?—Our scout-cells or receptors are sensitive to mechanical, chemical, and radiant stimuli of various kinds; and we may speak of (1) *mechano*-receptors, which respond, for instance, to the pressure of our friend's hand; (2) *chemo*-receptors, which respond, for instance, to the irritation of an acid on our fingers; and (3) *radio*-receptors, which respond, for instance, to the warmth of the fire. From the examples we have given it is plain that in the skin alone there are several senses, as Aristotle (384–322 B.C.) recognized long ago.

There are, moreover, other senses that we cannot exclude—the muscular sense by which we become aware of our movements, the sense of balance (located in the semicircular canals of the ear), the sense of pain, of hunger, of thirst, and of more besides. The fact is that the number of our senses is nearer twenty than five—and we must not forget common sense.

The Food-canal

Passing through the body-cavity, from the mouth to the terminal aperture (the vent or *anus*), there is the food-canal, over thirty feet in length. Except in the front of the mouth, it is lined with endoderm (the inner germinal layer); but this is enveloped in mesodermic tissue which includes many plain muscle-cells. As these contract they force the food onwards in a series of movements which are summed up in the technical term **peristalsis.** All the numerous pouch-like outgrowths of the food-canal or gut, e.g. lungs and liver, are necessarily lined with endoderm and enveloped in mesoderm.

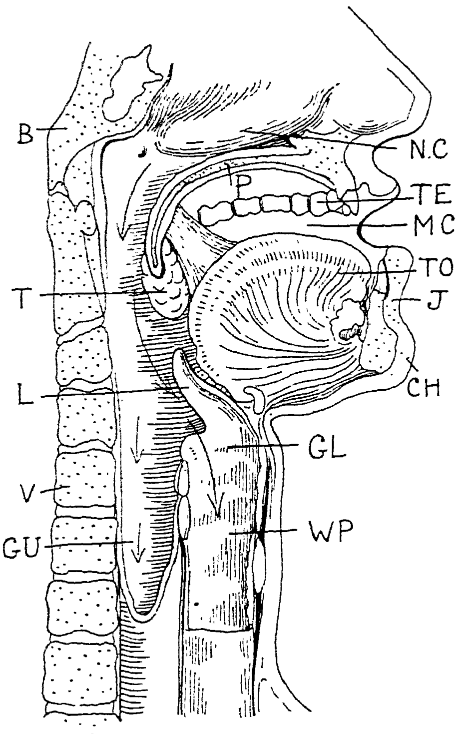


Fig. 454. Human Mouth and Throat in Section

B, bone; CH, chin; GL, glottis; GU, gullet; J, jaw; L, larynx; MC, mouth-cavity; NC, nasal cavity; P, palate; T, tonsils; TE, teeth; TO, tongue; V, vertebra; WP, windpipe.

It will perhaps make for clearness to leave the outgrowths until we have noticed the various regions, namely, (1) mouth-cavity, (2) gullet, (3) stomach, (4) small intestine, and (5) large intestine, which illustrate what is meant by division of labour. They form what in a backboneless animal, say a lobster or a cockroach, would be called the **mid-gut or mesenteron.** The Invertebrate's fore-gut or *stomodaeum* corresponds merely to the front of our mouth; and the Invertebrate's hind-gut or *proctodaeum* is practically unrepresented in Vertebrates.

THE MOUTH-CAVITY is bounded by the lips in front, the muscular and sensitive tongue on the floor, the cheeks on the sides, and the palate above. The muscular tongue helps in the backward pushing of the food and in altering the shape of the mouth in speaking, and is,

of course, the main organ of taste. The bony palate, which we can feel very readily with the tip of our tongue, is continued into the soft palate, from which a narrow median process called the **uvula** hangs down between the **tonsils.** The back of the mouth-cavity leads into the muscular **pharynx,** with which the food-canal proper begins; and near the junction of the two there are the paired openings of the posterior nares from the nasal chambers and of the Eustachian tubes

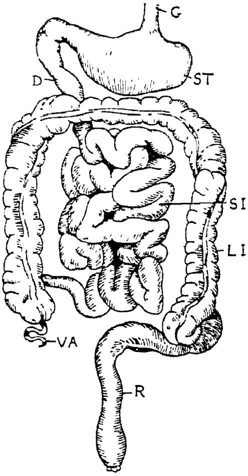


FIG. 455. DIAGRAM OF HUMAN ALIMENTARY CANAL

G, gullet; ST, stomach; D, duodenum; SI, small intestine; LI, large intestine; VA, vermiform appendix; R, rectum.

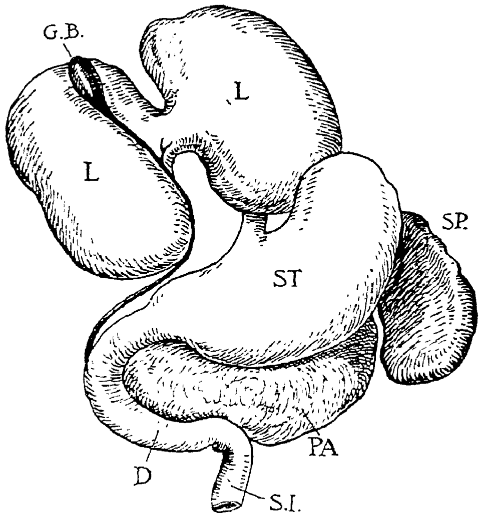


FIG. 456. DIAGRAM OF HUMAN DIGESTIVE ORGANS

GB, gall-bladder; L, liver; ST, stomach; SP, spleen; PA, pancreas; D, duodenum; SI, small intestine.

from the middle ear. On the ventral surface of the pharynx, the **windpipe** is given off, its opening being guarded by a lid—the **epiglottis**—which keeps food from 'going down the wrong way.' Beyond this opening the pharynx is continued on dorsally as the **gullet** or **oesophagus.**

Into the cavity of the mouth there open the ducts of three pairs of **salivary glands,** each of which is somewhat like a bunch of grapes. They produce a protein called **mucin** and a ferment called **ptyalin** (p. 927), which changes starch into sugar. This salivary secretion is poured into the mouth, and this is what we experience when our 'mouth waters' at the prospect of a pleasant dish.

The pharynx, as we have said, leads into the gullet, a tube about ten inches long, with muscular and elastic walls. It goes through the

midriff or diaphragm, a muscular sheet which separates the chest from the abdominal cavity, and passes the food onwards to the **stomach**, which lies to the left side of the body—one of the many examples of our lack of perfect bilateral symmetry.

The stomach is somewhat pear-shaped and can hold about four pints. It is moored to the abdominal wall by membranes called **mesenteries.** Internally it is lined by a glandular layer, secreting gastric juice, which includes the digestive ferment called **pepsin** and a little hydrochloric acid. Outside this, in the middle of the stomach-wall, is a muscular layer that churns the food. Externally is the glistening **peritoneum,** which lines the whole of the abdominal cavity and enswathes its enclosed organs. It is inflamed in peritonitis.

The beginning of the **small intestine** (or small bowel) is called the **duodenum,** and it receives the bile-duct from the liver and the pancreatic duct from the pancreas. There is a great length of small intestine—about twenty feet, and its chief function is to absorb the food digested by the ferments. The rest of the food-canal is the **large intestine,** about five feet long, which absorbs water and the residue of the food so far as it is available, and carries the undigested and indigestible residue (the faeces) to the anus. It is probable that our food-canal is much longer than is now necessary, in days of compact food and regular meals. The great length was better suited for our predecessors, whose food had more ballast in it. The evolution of our meals has outrun the evolution of our bowels.

Near the place where the small intestine joins the large, there is given off a blind process, the **vermiform appendix,** like a bent little finger. Its function is uncertain, and it is often the seat of trouble, the familiar appendicitis.

ANNEXES OF THE FOOD-CANAL.—Branching or pouching is characteristic of food-canals, and a reason for this may be found in the fact that the lining cells are abundantly fed and therefore multiply quickly. Thus there is surplus growth material, which may find an outcrop (1) in the great length of the alimentary tract, as in man's thirty feet; or (2) in the formation of thousands of intestinal **villi,** delicate processes that enormously increase the internal absorptive surface; or (3) in giving off pouches which carry the mesodermic sheath of the gut with them as they grow outwards into the body-cavity. In the human embryo the outgrowths occur in the following order: the four pairs of gill-clefts, the median thyroid gland, the lungs, the liver, the pancreas, and the allantoic foetal membrane, the stalk of which develops into the bladder. In many mammals there is a large *cul-de-sac* or caecum arising at the junction of small and large intestine, but this is represented in man by little more than the vestigial vermiform appendix.

THE LIVER.—This is the largest of the glands in our body, a lobed red organ lying below the diaphragm and chiefly to the right side. It weighs between three and four pounds, contains much blood, and is kept in its place by an investment of the peritoneum, which lines the body-cavity. The liver is a hard-worked organ, with manifold functions.

(1) The liver makes **bile,** a yellow, bitter fluid, which may pass by the bile-duct into the duodenum, or may be delayed for a little in the gall-bladder. It is partly of the nature of a waste-product, but it helps to a slight extent in digestion and in absorption.

(2) The liver makes **glycogen** out of the sugar (glucose) brought to it from the food-canal by the portal vein and its tributaries. This glycogen or animal starch is stored in the liver and is passed out (as sugar again) to the muscles as it is needed. The regulation of the concentration of glucose in the blood is another function of the liver, and in this it is helped by the hormone called **insulin,** which is formed in the pancreas.

(3) The nitrogenous carbon-compounds called **proteins** form an essential part of our food, and their large molecules are broken down by the digestive ferments of the stomach, pancreas, and small intestine to form the smaller molecules called **amino-acids,** which can pass more readily through the food-canal walls into the blood. They contain the nitrogen in the form of amino (or NH_2) groups. When the amino-acids are brought by the portal vein to the liver and there distributed, the amino-groups are split off to form ammonia (NH_3), which combines with carbon dioxide and water to form ammonium carbonate. By removal of part of the water, probably in the liver-cells, this compound is converted into **urea,** which is excreted from the body by the kidneys. The nitrogen-free residues of the amino-acids have either a carbohydrate or a fatty character, and are oxidized to supply energy to the body.

The liver has also to do with other affairs, such as the changes undergone by fats, but we have said enough to give a glimpse of the manifold work of this organ, which is the most important chemical clearing-house of the body.

THE PANCREAS.—This important digestive gland, called 'sweet-bread' in the ox, lies just below the stomach, and passes its complex secretion by the pancreatic duct into the duodenum. It includes three different ferments: (*a*) trypsin, which changes proteins into amino-acids; (*b*) amylase, which changes starch into sugar (maltose); and (*c*) lipase, which splits fat into fatty acid and glycerol or glycerine. The food which has been partly digested in the stomach forms a pulpy mass called **chyme.** Some of this is absorbed right away, but most passes into the duodenum, where it is acted on by the bile and by the

pancreatic juice, and becomes the fluid **chyle.** The pancreas, as we shall notice later on, has also an important function in producing the hormone called insulin.

Respiratory System

Behind the root of the tongue, on the ventral surface of the **pharynx** (badly called the throat), there is the **glottis** or opening of the windpipe (see Fig. 454). When there is any risk of some fragment of food slipping into the windpipe—very much ' the wrong way '—the larynx or voice-box at the beginning of the windpipe is instantaneously raised under the shelter of the root of the tongue, and a soft flap (the **epiglottis**) folds down over the opening. In this way what might be a common accident is really a rare one; and if a crumb gets through the doorway it is usually coughed up at once.

At the top of the windpipe there is a complex instrument—the **voice-box** or **larynx,** often popularly called 'Adam's apple.' In some people it is very conspicuous and moves up and down in a rather disconcerting way. It contains two membranous folds, projecting into the cavity and bounding a slit, whose shape and size can be altered considerably by the muscles of the larynx. The free edges of the two folds have elastic fibres, and are the **vocal cords,** which vibrate and produce sounds when the air passes over them, the sound varying with the size and shape of the opening for the moment. The supporting cartilages of the larynx—*cricoid, thyroid,* and *arytenoid*—turn out to be transformations of the gill-arches in fishes.

Below the larynx is the **windpipe** or **trachea,** lying to the ventral side of the gullet. It is supported by rings of cartilage, believed to be derived historically from gill-arches. The trachea divides into two **bronchial tubes,** which form the **lungs** by dividing over and over again into ever finer bronchial branches, ending in microscopic **air-sacs.** If a lung be compared to a bunch of grapes, the air-sacs would correspond to the fruits. Inside the bronchial tubes and the windpipe there is a moistening secretion and a lining of ciliated epithelium, whose living lashes are continually wafting dust-particles and the like up to the pharynx. The essential process is the interchange of gases between blood and air in the walls of the microscopic terminal air-sacs.

The reddish blood pigment (**haemoglobin**) in our red blood corpuscles captures the oxygen in the air-sacs, diffusion taking place through the delicate walls of the air-sacs and the capillaries. With a change to scarlet, the blood with oxyhaemoglobin passes back to the heart, and thence through the body, parting with the captured oxygen to the tissues and becoming dark purplish in colour. In this venous state (minus oxygen) it is hurried back from the body to the right side of

the heart, and thence to the lungs; and so it continues—from the place of capture to the place of oxidation, and back again. Just as the oxygen is captured through the walls of the air-sacs, so there is in the same place a getting rid of the waste gas carbon dioxide which has been collected by the blood-vessels from the tissues.

The lungs of the ox or the like are readily seen in the butcher's shop, and ours are like them—two large elastic bags filled with spongy tissue. They are actually made by the branching of the bronchial tubes, but these are embedded, as it were, in an elastic connective tissue very rich in blood-vessels, arteries coming in and veins leaving. The lungs fit the chest-cavity, but they lie freely except where the blood-vessels and the two bronchial tubes enter. They are invested by a delicate glistening moist membrane—the pleural membrane—which is continuous with that lining the inside of the chest. This membrane is inflamed when we suffer from pleurisy.

Our life depends on the ventilation of the lungs, and that depends on the enlargement and reduction of the size of the air-tight chest-cavity in which the lungs lie. In breathing in or **inspiration** the cavity of the chest or thorax is enlarged by movements of the ribs and of the diaphragm; and this enlargement has as a necessary consequence that air rushes in to the slightly expanded lungs. There is also a drawing in of blood into the sponge-work vessels. On the heels of this comes **expiration,** when the cavity of the thorax becomes smaller again, and the lungs shrink, and half a pint of air is driven out, about a tenth of the total contents. The expired air contains less oxygen (17 per cent) and more carbon dioxide (4 per cent) than the inspired air (oxygen 21 per cent; carbon dioxide 0·03–0·04 per cent); and if the alternation we have just mentioned does not take place, it is all over with us in a few minutes.

THE BLOOD.—We have in our body about ten pints of blood, and the whole is driven through and through us in ceaseless flow, about a mile in a day. The fluid, from which all the parts take and to which all the parts give, is a complex mixture and a subtle index to what is going on in the body. The blood fluid, with about 90 per cent of water, contains, on the plus side, some dissolved proteins, a little sugar, a little fat, much oxygen, and some **salts,** which in their nature and proportions bear a striking resemblance to the composition of sea-water, especially to that of the ancient sea inhabited millions of years ago by the animals that first had blood. The resemblance is a straw which shows how the evolution wind has blown. On the minus side the blood contains some nitrogenous waste and carbon dioxide, the latter being for the most part united with sodium carbonate to form sodium bicarbonate. The blood also carries **hormones** from the ductless glands, and **anti-bodies** or counteractives which parry the thrusts of poisons,

especially those which microbes make. Another subtlety is **anti-thrombin,** which prevents the blood from forming clots in normal blood-vessels. In some old or enfeebled people a clot may form in certain blood-vessels of the brain, and this often spells paralysis (a 'stroke') and death. As was said of old time: 'The blood is the life.'

But the blood is much more than its fluid or **serum,** it is a tissue. That is to say, it is a congregation of cells, though these happen to float in a fluid medium. Most numerous, though not countless, are the **red blood corpuscles** or **erythrocytes,** circular biconcave disks, $\frac{1}{3000}$th of an inch in diameter. As in other *mammals* they are non-nucleated after they are fully formed. In a healthy man there are about five million red blood corpuscles (and about 20,000 white blood corpuscles) in a drop smaller than the head of a pin, or, more precisely, in a cubic millimetre. In women there are said to be about half a million fewer in the same droplet. Though a mass of blood appears red, the individual red corpuscles are pale yellowish. This is due to the pigment **haemoglobin**—whose formula is often given as $C_{587}H_{1203}N_{195}O_{218}S_3Fe$. It is a protein (*globin*), in combination with a metallic pigment-nucleus called *haematin* (p. 938). Its peculiar value is that in the lungs it readily forms a loose union with oxygen and transports this to the living tissues of the body. It is continually changing from oxyhaemoglobin to haemoglobin, and back again. The red blood corpuscles seem to be rather short-lived cells, and are finished off in such organs as the liver and the spleen. Their ranks are recruited especially from the **marrow** of the bones, but the enlistment in the embryo occurs over a wider area, e.g. in the liver, the spleen, and the thymus (q.v.).

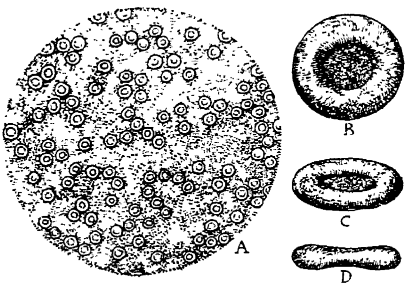


FIG. 457. MAMMALIAN BLOOD CORPUSCLES

A, general view of red corpuscles in sample of blood. B and C show surface view, and D shows side view of these biconcave red blood corpuscles, which are non-nucleated.

The **white blood corpuscles** or **leucocytes** are nucleated non-pigmented cells, inclined to be spherical, but often slightly amoeboid (see AMOEBA). They are few in number as compared with the red blood corpuscles, about 1 to 500 or 600. There are several different kinds, and among these the **phagocytes** are of special interest because of their capacity for engulfing and digesting intruding microbes (*phagocytosis*). Their cradles are in the lymph-glands, the tonsils, the marrow, and elsewhere.

THE VASCULAR SYSTEM.—What should every one understand in

regard to the circulation of the blood? We may say that the use of the blood in an ordinary backboned animal is fivefold. (1) It distributes throughout the body the digested food by which the living tissues are kept in repair, and by which the engines of the body, the muscles, are enabled to continue contracting. (2) It carries the oxygen quickly from the place of capture, say the lungs, to the place of combustion, say the muscles; and it likewise carries the carbon dioxide gas from the place of formation, say the muscles, to the place of liberation, say the lungs. (3) With the help of the lymph, which bathes the tissues very intimately, the blood collects the soluble nitrogenous waste and takes it to the filter, notably the kidneys, by which it is excreted. This fine nitrogenous waste is partly due to the wear and tear of the living tissues, and partly to the unused residue of digested nitrogenous food distributed by the blood. (4) From the ductless glands or organs of internal secretion, such as the thyroid gland and the suprarenal bodies, the blood carries away certain potent chemical messengers or hormones which are distributed throughout the body, regulating the various functions, and making the body more of a unity. (5) The blood has also a protective rôle, for among the white blood corpuscles there are some called 'phagocytes' (p. 1320) which are able to engulf and digest invading microbes. These phagocytes leave the blood-vessels altogether and serve as a mobile bodyguard, and they also help in processes of wound-healing and the like. Moreover, some of the white blood corpuscles are able to form, in the fluid or serum of the blood, certain anti-bodies which counteract poisons. It is plain, then, that the blood is a very important fluid-medium, from which every part of the body takes and to which every part likewise gives. It is indispensable that it should be kept in circulation and that with rapidity.

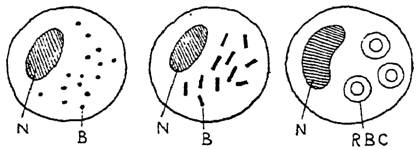


FIG. 458. PHAGOCYTOSIS

N, nucleus; B, bacteria; RBC, red blood corpuscle.

What Harvey showed was that the blood moves quickly round in a circle, from the heart to various parts of the body and back again to the heart. But we require a more detailed picture.

There are two pumps lying side by side in the **heart** of any of the highest Vertebrates, that is to say, the birds and the mammals. The right pump (or **ventricle**) drives impure blood to the lungs, whence there is a return of pure blood to the left receiving chamber (or **auricle**) of the heart.

From the left auricle the purified blood, i.e. relatively rich in oxygen and with little carbon dioxide, passes into the left ventricle,

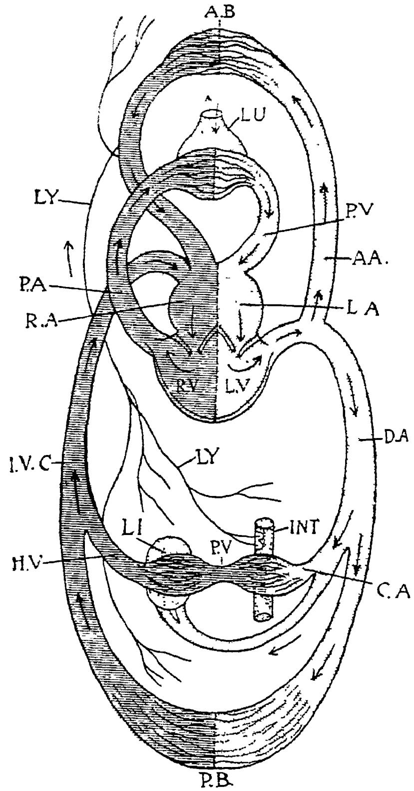


FIG. 459. DIAGRAM OF BLOOD CIRCULATION IN A VERTEBRATE

RA, right auricle receiving inferior vena cava (IVC); RV, right ventricle giving off pulmonary artery (PA) to lungs (LU); LA, left auricle receiving pulmonary vein (PV); LV, left ventricle giving off aortic arch (AA) and dorsal aorta (DA); AB, anterior portion of body; HV, hepatic vein; LI, liver; PV, portal veins; INT, intestine; CA, coeliac artery; PB, posterior portion of body; LY, lymphatic vessels. The arrows indicate the direction of flow of the blood.

which drives it to the body by the **arteries.** The arteries end in fine capillaries which penetrate everywhere, bringing the tissues what they need. From the arterial **capillaries** the blood passes into venous capillaries, as Leeuwenhoek first discerned, and thence into the **veins,** which bring it back to the right auricle of the heart.

The left pump of the heart drives pure blood (*a*) to the tissue of the heart itself, for the engine itself must be kept effective; (*b*) to the stomach and intestine; (*c*) to the kidneys; and (*d*) to the head, trunk, limbs, and body generally. The great artery that leaves the left ventricle and gives off the appropriate branches (*b–d*) is called the **aorta.**

The impure blood from the head region is brought back to the right auricle of the heart by superior veins (**superior venae cavae**), and from the posterior body by a large vein (**inferior vena cava**). Into this posterior vein there also passes, (1) by the **renal vein,** the blood which has been filtered in the kidney as regards its nitrogenous waste-matter; (2) by the **hepatic vein,** the blood from the liver, which mediates between the general circulation and the portal system, bringing in the digested proteins and carbohydrates from the stomach and intestine; and (3) the blood from the tissue of the heart itself.

The vessels which bring back blood *to* the heart are the veins, and all of them carry venous or

impure blood except the **pulmonary veins** from the lungs, which bring the oxygenated blood into the left auricle. The vessels which carry blood *from* the heart are the arteries, and all of them carry pure blood except the **pulmonary arteries,** which bear the impure blood from the right ventricle to the lungs.

THE HEART HORMONE.—To get a glimpse of deeper things, let us glance at the familiar beating of the heart. There is, perhaps, no problem in physiology which has been so deeply investigated and so thoroughly discussed, but we cannot do more than illustrate its nature.

We know that each individual one of the rhythmic muscular movements of breathing is initiated by a nervous impulse travelling down from the 'respiratory centre' of the brain; but, although the heart has a double nerve-supply, the fact that the frog's heart, for instance, may beat for hours after being removed from the body, shows that the rhythm of the heart is independent of these nerves. They act, indeed, as controls—as accelerator and as brake—but the heart may continue beating without their aid. However, there are also nerve-centres (ganglia) in the heart itself, and at one time they were regarded as the seat of the rhythm; but, in the higher animals at least, this is not the case. It is more difficult to be sure that the fine network of nerve-fibres, which runs through the muscular walls of the heart, plays no part in the process. Nowadays, however, it is considered that the rhythm, on which the regular succession of beats depends, is inherent in the muscle-cells themselves, especially in a group of modified muscle-cells, the 'node,' situated near the opening of the great veins. The most conclusive evidence for this view is to

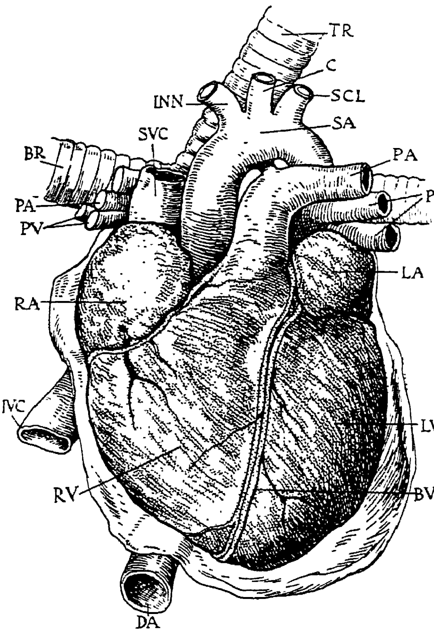


FIG. 460. THE HUMAN HEART

BR, bronchus; BV, blood-vessel; C, common carotid artery; DA, dorsal aorta; INN, innominate artery; IVC, inferior vena cava; LA, left auricle; LV, left ventricle; PA, pulmonary artery; PV, pulmonary vein; RA, right auricle; RV, right ventricle; SA, systemic arch; SCL, subclavian; SVC, superior vena cava; TR, trachea.

be found in the fact that a group of muscle-cells taken from the heart of an embryo-chick and kept alive in a nutrient solution under the microscope (by 'tissue-culture' methods), will show rhythmic contractions as long as they live.

Now, it is a property of muscle-tissue in general, and of the heart-muscle in particular, that, after responding to a stimulus (by contracting), it remains for a short period 'refractory'; that is, it does not respond to any further stimulus until, after a short time, it has recovered from the effects of the first. So that, whatever the stimulus which causes the heart-muscle to contract may be, it is unnecessary to suppose it rhythmic in nature; since, owing to the intervention of the refractory periods, the heart-muscle will respond to a *continuous* stimulus with a *rhythmic* series of beats.

A recent step forward is to be found in the work of Haberlandt and of Demoor. They have shown that extracts made from certain portions of the heart, especially from the 'node' tissue in which the rhythm is most manifest, and which acts as the 'pacemaker' of the heart, have the property of strengthening and quickening the beat, or even of reawakening to activity a heart which has stopped. They suppose that these extracts contain a specific chemical substance which they call the 'heart hormone' (by analogy with the other hormones or chemical messengers of the body), and that it is the presence of this substance which stimulates the heart to contract. Chemically, nothing is yet known of this hormone except that it is not apparently recognizable as any known drug or product of the body, and physiologically there remains much to be explained. But there seems no doubt that in this suggestion a new chapter in our knowledge of the heart has been begun.

THE LYMPH.—The blood flows in a *closed system* (except apparently in the meshwork of the spleen), the ends of the arteries (*from* the heart) joining the beginnings of the veins (*to* the heart) by means of the invisible **capillaries.** Thus the blood does not in the strict sense wash the tissues, and the middleman, as it were, is the **lymph.** This is a turbid, slightly yellowish fluid, with colourless cells like some of the white blood corpuscles. Some of the lymph that is always being changed by its intermediation between the blood and the tissues seeps back into the blood-vessels, and the rest is collected in delicate **lymphatic vessels** which are to be found almost everywhere in the body. They unite to form larger vessels, and eventually two ducts which enter the venous system, as we shall notice presently, one on each side of the neck. At various parts of the course of the larger lymphatic vessels there are numerous so-called glands, rounded bodies sometimes as large as a hazel-nut. They are especially developed in the region of the neck, the armpit, the groin, the roots of the lungs, and the mesentery

of the intestine; and they affect the lymph that passes through them, so that it is better suited to join the blood system. They also serve as retreats into which the wandering phagocytes may carry their captured microbes, and this fact helps us to understand why the glands sometimes swell up or are 'inflamed' when invading microbes are being dealt with. We may also repeat that some of the white corpuscles are born and cradled in the lymphatic glands.

We are lingering over the lymph system because most laymen find it difficult to understand, even in an elementary way. To complete our outline we must refer back to the small intestine where the digested food is being absorbed. The products of the digestion of proteins and carbohydrates are absorbed by the fine branches of the mesenteric vein, which are distributed in the wall of the intestine; but the lymphatic vessels or **lacteals** in the intestinal villi absorb the fatty acids and glycerine. These products of digestion are carried to numerous mesenteric lymphatic glands or **mesenteric glands,** many of them about the size of an almond, in which useful changes occur. And from these the lacteals conduct the material (modified chyle) into a single duct, the **thoracic duct.**

This thoracic duct is fifteen to eighteen inches long and about the diameter of a small crow-quill; it receives not only the lacteals from the intestine, but the lymphatics from the legs, the left arm, and the left side of head and chest; it has valves which direct the flow *forwards*; it opens on the left side of the neck at the junction of the veins from the neck (jugular) and the arm (subclavian). At the corresponding place on the right side the lymphatics of the rest of the body unite to form the *right lymphatic duct.*

In the centre of lymphatic glands there is often a peculiar kind of connective tissue, forming a network with many lymph corpuscles in the meshes. This is called lymphoid or adenoid tissue. The word **adenoids** is applied to masses of similar spongy tissue which often occur at the back of the nose and pharynx in young children. As adenoids interfere greatly with proper breathing, they have often to be removed —an operation which usually brings much reward in the way of invigorated life.

THE THYMUS.—Somewhat like a lymphatic gland in structure is the thymus, which lies near the foot of the windpipe and between the breastbone and the heart. It is sometimes called the neck sweetbread. There is great uncertainty in regard to its function, but it usually disappears at puberty, and is therefore regarded as having to do with the development of the sex-organs.

THE SPLEEN.—This much-discussed organ lies to the left side of the stomach, flat and thin in shape, red in colour, and five inches in length. Its functions are somewhat puzzling. When it has to be

removed from a man he seems to get on very well without it; but this probably means that other parts are doing its work. It has no connection with anything but blood-vessels and nerves. Its rather spongy structure includes much smooth muscle, and there is a regular ebb and flow of blood once a minute, besides minor contractions and expansions which keep time with the breathing movements and heart-beats. It is almost like an accessory heart. It is peculiar, if not unique, in showing some lack of continuity between the ends of the arteries and the beginnings of the veins within the pulp-tissue. In other words, there is an interruption in the continuity of the capillaries within the spleen.

The spleen is a cradle and a destructor of red blood corpuscles. It is also probable that it is one of the birthplaces of white blood corpuscles. It seems to be an active and sensitive organ, as the ancients thought, for it thrills (in some animals at least) to big changes in the body or in the surroundings.

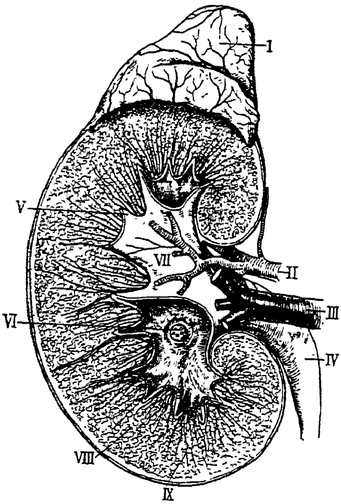


FIG. 461. SECTION OF A KIDNEY
I, supra-renal body; II, renal artery; III, renal vein; IV, ureter; V, pelvis or cavity of the kidney; VI, pyramid; VII, branches of renal artery; VIII, medulla; IX, excretory tubules.

THE KIDNEYS

These dark-red organs, about four inches long by two broad, lie far back in the abdomen, on each side of the backbone. Their shape, like a kidney bean, is much the same as in the sheep, familiar in its cooked state. When we halve a sheep's kidney longitudinally with a knife we see a darker cortex, consisting of the filtering tubes, markedly different from the paler medulla, which consists of coiled collecting-tubes. These converge into the expanded mouth of the white **ureter,** which carries the waste or **urine** to the **bladder,** where it is stored till got rid of.

The kidneys are intricate and very effective filters introduced into the blood-stream, and helping greatly to keep the composition of the blood constant by getting rid of surplus and injurious substances, but **urea** above all, the end-product of the nitrogenous part of the proteins. The composition of urea is $(NH_2)_2CO$; it was the first organic animal product to be built up artificially or synthetically (by Wöhler in 1828).

The Reproductive System

In some ways it is useful to describe the reproductive system apart from the rest of the body, for it has mainly to do with a periodic function and not with the everyday life, and it has mainly to do with the continuance of the race and not with the individual welfare. And yet in higher animals the **ductless glands** of the reproductive organs are continually contributing useful **hormones** to the body and assisting in the vigour of the individual. Therefore we must seek for a middle way: the reproductive system influences the general body and the activities of the body influence the reproductive system.

The essential reproductive organs or **gonads** are the seats of the production of the **germ-cells,** the testes or testicles in the male producing sperm-cells or spermatozoa, the ovaries in the female producing egg-cells or ova. Besides the essential organs there are accessory structures, notably (1) the ducts by which the germ-cells are liberated, or by which, in the female, the offspring may be born; (2) various kinds of glands; and (3) external parts which are of use in sexual union.

THE MALE.—The sperm-producing organs or **testes** of the male begin their development in the abdominal cavity, where the ovaries in the female begin and continue. In both cases these essential organs, conveniently called gonads, arise from clusters of germinal cells that do not share in body-making (see HEREDITY). So that we may say that the sexes begin alike as regards general appearance and mode of development.

As in most mammals, so in man, the two testes descend before birth into a pouch called the **scrotum,** which protrudes at the lower end of the abdomen, with the coupling organ or **penis** lying in front. In marsupials or pouched mammals, like kangaroos, we may notice the unique arrangement that the scrotum is in front of the penis.

At **puberty,** when the voice breaks and many other changes occur, the testes begin to be mature, i.e. able to produce fully formed spermatozoa. These testes, in the scrotum, are about the size of pigeons' eggs, and consist of a large number of delicate tubes—the **seminiferous tubules**—on the walls of which there is a profuse multiplication of sperm-cells, so that hundreds of millions are formed in the course of life. In adolescence and afterwards some of these invisible spermatozoa are got rid of in the urine, for the exit duct from the testes joins the exit duct from the bladder; and some of them are got rid of *involuntarily* in 'nocturnal emissions.' At the proper time they may be passed into the female in sexual union, and they may also be passed out by abnormal self-excitement or masturbation, which is apt to have injurious results. Let us notice the path of discharge.

The tubules that produce the sperm combine to form *efferent vessels,*

and these lead into a much-coiled tube which forms a mass (the **epididymis**) at the posterior margin of the testis. This long convoluted tube leads into the muscular male duct or **vas deferens**, which, in turn, opens with its fellow from the other side into a median sac. This unites with the **urethra** from the bladder to form the urinogenital canal, which perforates the muscular penis and is the common out-passage for urine from the bladder and sperms (or **semen**) from the testes. In man and in some mammals there are two accessory reservoirs called **seminal vesicles**, which arise at the outer ends of the vasa deferentia and lie behind the bladder.

In sexual union, i.e. coition, copulation, or coupling, the external male organ or penis is inserted into the female genital aperture and liberates the seminal fluid into the female duct or **vagina.** The successful performance of this sexual act requires the erection of the penis, a reflex change instigated by nervous messages from the spinal cord and the brain, and largely brought about by the gorging of the organ with blood. What is normally a flaccid organ becomes turgid and stiff. In a rather complex reflex way the insertion of the organ is followed by a discharge of the seminal fluid from the seminal vesicles or vasa deferentia.

A **human spermatozoön** is about one-five-hundredth of an inch in length, but the essential part (the 'head' and 'middle piece' described elsewhere) is only about one-tenth of this. The spermatozoa move by means of their actively undulating 'tail,' and their movement is helped in some types by rows of cilia on the female genital duct. They pass through the **uterus** upwards, and one of them may meet and fertilize a descending ovum.

In the human species the usual occurrence is that only one ovum is fertilized at a time; but several may be liberated at once from the ovary, and by the fertilization and development of two ova there arise **ordinary twins. Identical twins,** who are always of the same sex, arise in a different way, when one fertilized ovum develops simultaneously into two embryos. Unfertilized ova, which cannot come to anything, die away in the genital duct; and the same is true of almost all the spermatozoa. Nature, as we say, works with a big margin as regards germ-cells.

We must not close our brief outline of the male organs without noticing that among the seminiferous tubules of the testes there are some **interstitial cells** which produce a special **sex-hormone.** This is distributed through the body by the blood, and evokes puberty-changes and the like in susceptible organs and tissues.

THE FEMALE.—In many animals the whole function of the female as such is to produce eggs. Thus the only obvious difference between the female sea-urchin and the male is that the former is an egg-producer and the latter a sperm-producer. No doubt there are microscopical

and biochemical differences between the sexes even in sea-urchins, but in these animals, and in many others of low degree, the males and females are practically alike except in the fundamental difference in the gonads. In animals of higher degree, however, we have to take note of accessory differences between the sexes, e.g. as regards the genital ducts and external appendages, as is well illustrated, say, in insects. There may also be marked secondary sex-characters, as in size, colour, decorations, and so forth. But at various levels there is another kind of difference, that the female is specially adapted as a mother. Thus there may be organs for egg-laying (e.g. ovipositors in fishes), and organs for nourishing and carrying the young before and after birth (e.g. in mammals). Our point is that in the human body, as in many others, one must recognize organs that are adapted for the care of the offspring (e.g. milk-glands), as well as the essential organs (the ovaries) that are concerned with ovum production.

THE OVARIES.—These two essential organs, in which ova grow and multiply, are situated on the posterior abdominal wall in the waist region, not far from the hip-girdle. They are well supplied with blood-vessels and nerves. They develop, as the testes do, from patches of germinal cells that do not share in the body-making of the developing organism, but they produce only a small number of egg-cells as compared with the millions of sperm-cells. At an early stage in their development the ovary shows a superficial germinal epithelium which includes some primitive germ-cells, and this dips down into a core of **stroma,** consisting of fibrous and vascular tissue. Nests of germinal cells, each with a single unripe ovum (or **oöcyte**), become surrounded by stroma, and each nest is called a **Graafian follicle.** The cells of the nest inside the stroma are called the follicle-cells, as distinguished from the special primitive germ-cell (or its direct descendant) which is becoming an **ovum.** Some of the follicle-cells are peripheral, others form a disk around the ovum; between the two layers of follicle-cells a little fluid develops, and as the follicle becomes larger it returns to the surface of the ovary, from which the germinal epithelium and the primitive germ-cells had previously grown inwards. On the surface of the ovary the Graafian follicle bursts, a process called **ovulation,** which begins in the girl at about the age of fourteen, and continues regularly at intervals of about four weeks. In most cases only one ovum is set free at a time.

Inside the burst follicle a remarkable process occurs—the formation of a **corpus luteum,** which means 'yellow body.' The residual follicle-cells or an ingrowth of surrounding epithelial cells rapidly form a large glandular body of a yellowish colour, which seems to have important hormone-producing functions. Its secretion is credited with influencing the preparation of the uterus or womb, the early nutrition of the embryo, and the multiplication of cells in the milk-glands. Some of its

accredited functions probably belong to the secretory activity of the follicle-cells apart from any luteal development. Moreover, there are some **interstitial cells** in the ovary which seem to be hormone-producing, like the corresponding cells in the testes, and are believed to influence the phenomena of ' heat ' in various mammals, the behaviour of the uterus during pregnancy, and the process of menstruation, which will be referred to later on.

The ripe **human ovum** is like many another, a relatively large spherical cell, one-hundred-and-twenty-fifth of an inch in diameter. It is surrounded by a thick transparent membrane (the *zona pellucida*); its living matter contains a little in the way of yolk; and there is a relatively large clear nucleus containing forty-eight chromosomes which carry many of the hereditary factors or ' genes,' or perhaps all of them.

THE DUCTS.—When an ovum bursts from its Graafian follicle on the surface of the ovary, it is caught by the temporarily apposed mouth of the **Fallopian tube,** the anterior portion of the **oviduct.** Here the egg-cell is fertilized by one of the ascending sperm-cells, and division or segmentation forthwith begins.

The fertilized ovum passes on into the next region, the **uterus** or **womb,** formed from the fused middle regions of the two oviducts. In many mammals, such as the rabbit, these regions do not fuse, and there are two uteri; but in the human species and its near relatives there is but one. It is in the uterus that the segmenting egg is fixed, and proceeds to develop into an embryo or **foetus.** This becomes intimately attached to the mother by means of the **placenta,** a complex structure, partly maternal and partly embryonic, which allows of a close partnership between the mother and her unborn offspring.

The wall of the uterus undergoes intensive and extensive preparation for the reception and subsequent nurture of the young life, and there are some remarkable intricacies which assist in this. One of these is the process of **menstruation**—a discharge of blood and shed cells—which occurs regularly every twenty-eight days and prepares the wall of the uterus for the reception of an ovum. It has been observed in apes and monkeys; and somewhat analogous processes occur in certain other mammals. Menstruation is dependent biochemically on the ovary, and there is usually a liberation of a ripe ovum from the ovary towards the later part of the menstrual period.

Below the uterus is the vagina into which the male organ is inserted in sexual union, and down which the offspring in due time passes after its long **gestation** of nine months. During this period the uterus is greatly enlarged, in relation to the growth of the foetus; the menstrual discharges cease; there is a preparation of the **mammary glands.** Eventually, in parturition, the strong contractions of the uterus lead to the birth of the child, whose independent life thus begins.

Man as a Museum of Vestigial Relics

In old churches on the Continent we sometimes see precious collections of relics, but we have a much older collection in our own body. Man is a peripatetic antiquarian museum, both in body and mind. In the case of the body, at any rate, there is no doubt as to the authenticity of our relics—such as the muscles which some people can use in moving their ear-trumpet or in twitching their scalp. These are vestiges of stronger muscles which were in everyday use in long-lost ancestors.

Darwin compared the **vestigial structures** in our body, or in the bodies of animals, to the unsounded letters in certain words, such as the ' o ' in leopard, or the ' b ' in doubt. This was a good comparison, for the letters in question are of no use, though their disappearance would rob us of an interesting clue to the history of the words. Similarly with vestigial organs in the body: they are functionless, but they are clues to history. If the human embryo has gill-clefts, they must have been in man's very distant ancestry, hundreds of millions of years ago, fish-like animals breathing in water. The only fault we have to find with Darwin's analogy is that the unsounded letters are just as large and prominent as the sounded letters, whereas vestigial structures are always in some measure *dwindled*.

Some museums do great service in exhibiting what may be called the evolution of mechanisms, such as bicycles and steamships, railway locomotives and pianos. These exhibits show the gradual advance from stage to stage, and are very instructive. One peculiarity about them that strikes the student of animal evolution is that they show so little trace of vestigial structures. The mechanisms that we mentioned are very intricate, but so far as we know they have almost no parts that are not of use. Our body, on the contrary, swarms with relics. Part of the reason for this difference is that as the mechanism is gradually improved from decade to decade, it is very severely criticized in reference to utility and economy. Another reason is that the machine is evolved from without by man, whereas the living creature is evolved from within and cannot shake off the hand of the past, which is as a matter of fact its inheritance.

On the other hand, when we pass from machines to clothing, where criticism or selection for utility and economy is less stringent and where the changes are influenced by subtle factors like fashion and taste, we find many instances of vestigial structures. Thus in a man's jacket every one is familiar with buttons at the wrist that are never used, though there are often three on each side. In most cases they cannot be unbuttoned, yet they are the relics of buttons which used to be of use in folding back the sleeve. The same is illustrated by the buttons at the small of the back on a morning coat,

once used in fixing up the tails. As to button-holes, they often make no pretence at being openable, but are quite vestigial.

At the inner angle of our eye there is a minute red glandular swelling called the **caruncula,** and between it and the eyeball there is a vestige of the **third eyelid** or **nictitating membrane.** This is larger in some races than in others, and in some negroes it includes a cartilaginous support. In many reptiles, in almost all birds, and in most mammals, the third eyelid, also called the **plica semilunaris,** is well developed, and is used to cover and clean the surface of the eye. It is well seen in rabbit, ox, and cat, and most of us have noticed it being flicked across a bird's eye. It is absent in whales and dolphins, and this may be associated with the fact that the front of the eye is continually washed with water. It is a vestige in apes and man, and this may be associated with the mobility of the upper eyelid. In any case it is one of our precious relics.

If we examine the skull of almost any mammal, a sheep's, let us say, we see two openings far forward on the roof of the mouth. **Naso-palatine openings** they are called, for they lead from the front of the bony palate to a gristly scroll in the nasal chamber, which encloses a sense-organ called the **organ of Jacobson** after the anatomist who discovered it. It is made of cells like those that occur on the smelling-patches inside the nostril, and it is almost certainly an auxiliary olfactory organ. It has been called an outpost of the nose, and it is probably very useful in helping animals to detect some unwholesome odoriferous ingredient—say a poisonous plant—in the food that they have taken into their mouth. Now this paired organ of Jacobson began in reptiles and is well developed in many mammals. But in man it is a vestige, often disappearing altogether; and the two openings are closed. The same relic is to be found in the ape's museum.

In Wiedersheim's notable book, *The Structure of Man, an Index to His Past History*, there is a discussion of over eighty retrogressive or vestigial structures in man, wholly or in part functionless, some appearing in the embryo only. This long list is a little apt to give a false impression because it includes a large number of small dwindling muscles, such as those mentioned above by which some people can move their ears like donkeys. On the other hand, the interest of a vestige does not depend on its size. A dwindling tag of muscle may be an eloquent guide to the path of evolution.

Care should be taken to keep by themselves all those dwindling structures for which some function is still demonstrable. Thus we do not agree with the great anatomist to whom we have referred in including in the human museum the **pineal body** which rises from the upper surface of the brain, for although it may be retrogressive in man, as compared with its state in the New Zealand lizard (*Sphenodon*),

where it is distinctly a third eye, yet it seems to form part of our regulatory or hormone-making system, especially in youth. It seems a sad irony that a modern anatomist should rank as vestigial not only man's wisdom teeth, but the organ which Descartes regarded as the seat of the soul.

Races of Mankind

THE HUMAN SPECIES.—It is convenient and correct to speak of mankind, including in that word all true men (*Homo*). Why is the use of this common word to be approved of, whereas we do not speak of 'bird-kind' or 'fish-kind' or 'insect-kind'? The answer is partly that all living men are of one kind or species, technically known by the name *Homo sapiens*. The word 'species' is not much more than a scientific synonym of the old-fashioned word 'kind.' Thus we read in the translation of the Old Testament that the Lord said unto Noah: 'Of the various kinds of birds, the various kinds of mammals, and all the various kinds of reptiles, two of every kind are to join you, that you may keep them alive. Take also some of every kind of edible plant, and store it by you, to be food for yourself and them.'

SPECIES DEFINED.—But it is necessary to linger for a little over the scientific definition of 'kind' or 'species,' so that we may be clear what we mean when we say that all men and women, since history began, belong to the same species, *Homo sapiens*.

(1) A species is a group of similar individuals, agreeing with one another, and differing from members of the groups most nearly resembling them in a number of lasting characters which are not trivial, but are always greater than any of those that frequently occur within the limits of a single family. (Thus it would never do to divide mankind into different species according to the colour of their hair, for it is easy to find three brothers markedly contrasted in that respect; and so for many other relatively trivial features.)

(2) The members of a species must breed true; that is to say, there must be some degree of constancy, from generation to generation, in the hereditary characters which are taken to be characteristic of the species. (Yet this must not be pressed too hard, for many species are continually showing new departures or variations even as regards their 'specific characters,' and some species are given to 'sporting,' that is to say, to producing abrupt 'mutations' in their progeny. A boy with unusually fine eyesight would be a variation; a 'calculating boy' would be a positive mutation, and a boy with no colour in his hair or eyes a negative one.)

(3) Theoretically the members of a species are all fertile with one another, but they are not readily fertile with the members of other species. (In man's case no known exceptions occur to this rule, for

modern man has no near relatives. In very far back times, however, it is possible that *Homo sapiens* sometimes crossed with an older species, *Homo neanderthalensis*, which eventually became extinct.) In many living creatures there is occasional successful crossing between different species, e.g. between two different kinds of duck, or between two different kinds of pheasant. In some cases the crossing results in vigorous offspring, but these are barren or sterile, either invariably or usually. Thus a mule is the fine result of crossing a pony mare and a jack donkey; but to the male mule's sterility only one exception is recorded, while the female is only occasionally fertile, when crossed with a donkey. It is this unlikelihood of successful crossing that keeps species distinct from one another. Thus a rabbit and a hare are not very far apart, but they are not known to cross. The widespread belief that what are called 'leporides' are crosses between hares and rabbits is quite erroneous; and a 'Belgian hare' is simply a kind of rabbit. Many precisians among zoologists regard rabbit (*Oryctolagus*) and hare (*Lepus*) as different *genera*. Here it may be noticed that the fabulous 'Brer Rabbit' of many different countries was almost certainly based on a hare.

(4) Specific characters do not readily change even when the surroundings, habits, and food are much altered. Every healthy child is at once recognizable as a member of the human species though the conditions of upbringing may be very different, and may have brought about diversities in size and strength and other modifiable features. There are many species of plants and animals which are just the same, even to minute details, though the conditions in which they live are very diverse. On the other hand, there are many species that are known from one habitat only, and it is quite possible that some of their more superficial features, believed to be hereditary, are hammered on to each successive generation. This should be made the subject of experiment.

To sum up: *A species is a group of similar individuals differing from other groups in a number of more or less true-breeding characters, greater than those which often occur within the limits of a family, and not the direct result of environmental or other nurtural influences. The members of a species are fertile with one another, but not readily with other species.*

ORIGIN OF RACES.—Every one knows that the members of a human family are often very different from one another. Two brothers may be more unlike than two cousins. This is one of the great facts of life, that variations or novelties are always occurring (see VARIATION). Something of the nature of a new pattern crops up—a kitten with long fluffy hair, a calf without horns, a greater celandine with its leaves all cut up, a rose thickly covered with prickles, and so on through a very long list. These new departures, especially those of a type called

mutations (q.v.), may be short-lived and thus come to nothing, or, while vigorous themselves, they may have no offspring to continue their peculiarities; but in some cases they flourish and multiply and are the beginnings of new ' varieties,' ' breeds,' ' races,' or ' species,' as the case may be (see DOMESTICATED ANIMALS).

When man took to breeding the wild rock-dove (*Columba livia*) he was pleased with certain variations that cropped up, such as a pigeon with extra feathers on its tail or with a crest on its head. He set these apart and paired them with others like themselves, and so he gradually established different ' breeds,' groups of similar individuals, mostly producing offspring like themselves, i.e. **breeding true.** When he continued this pairing of similar strains and sifting out of those that he did not wish, he advanced the breed to the somewhat firmer position of a **race.** There are differences of opinion as to the best use of these words ' breed ' and ' race,' but we are here using the word ' race ' to mean a group of true-breeding derivatives of an originative species, which pair with one another more readily than with the members of another race. Thus there arose the races of fantail, homer, tumbler, jacobin, pouter, and other pigeons.

Now let us turn to man himself. As we have said, there is reason to believe that all the different races of mankind belong to one species, *Homo sapiens*, who may be distinguished from the extinct Neanderthal species, *Homo neanderthalensis*, and others more remote. Among the original more or less homogeneous members of the species *Homo sapiens* variations occurred, and when a number of similar variations became separated off from the main body by emigration or by insulation, and thus tended to breed together, there would be or there might be a beginning of distinct human breeds, and by and by races. Just as we see distinct species of animals arising on islands, where the range of intercrossing is necessarily narrowed, and similar variants readily pair with one another, so it is likely that insulation or isolation played an important part in the origin of the different races of mankind. But Nature's sifting would also help, for if very blond variants arose in a young race that had migrated to a warmer country, they would tend to be sifted out, since they do not stand the glare of the sun so well as dark-skinned people do. So far, then, we may sum up by saying that the races of mankind depended to begin with on **variability,** and that their establishment was effected partly by some form of isolation, which brought about close **inbreeding,** and partly by the action of **natural selection,** which sifted out the unprofitably divergent members of each stock. It is probable that the uniformity of characters in a race was sometimes helped by **sexual selection** or preferential mating. If the men tended to have a similar taste for a particular type of feminine beauty, or if the women tended to prefer a particular type of

masculine handsomeness, this consistent preference would tend to make the tribe more homogeneous. When races diverged *far* from one another, their members sometimes became more or less repulsive to one another. Moreover the crossing of two races widely separated from one another is rarely a success as regards the offspring.

RACE PREJUDICE.—In mankind a new tribe in the making may be isolated by physical barriers such as those due to a new bend in a river, a flow of lava, a sandstorm, a subsidence of the earth's crust, and so forth; but it may also be that the members of a new tribe have a 'prejudice' against marrying with the members of other tribes or of the parent tribe. Thus new tribes become well defined and stable, and what we now call 'race prejudices' may once have been of great value in helping to mark off new tribes and races. Those young tribes that had no prejudices in favour of keeping themselves to themselves would tend to disappear, and this is what Sir Arthur Keith means by saying that there may often have been 'survival value' in race prejudice. 'Each tribe in our prehistoric world represented an evolutionary experiment. Without isolation Nature could have done nothing. How did she keep tribes apart?' No doubt topographical barriers helped to secure this object, 'but Nature did not trust to them. She established her real and most effective barriers in the human heart. These instinctive likes and dislikes of ours, which I speak of as prejudices, have come down to us from the prehistoric world. They are essential parts of the evolutionary machinery which Nature employed throughout eons of time to secure the separation of man into permanent groups and thus to attain production of new and improved races of mankind' [Keith, *The Place of Prejudice in Modern Civilization* (London, 1931), p. 54]. And Sir Arthur Keith goes on to show that the spirit of independence in young tribes would work in the same direction as race prejudice. We must ask ourselves, however, how far it may now be necessary to correct our inborn race prejudices by a sense of the interdependence of the peoples of the world and their interests. We may surely learn to care more for other peoples without lessening our love for our own country.

CHARACTERS OF HUMAN RACES.—Before we try to map out the different races of mankind, let us ask what characters are taken as the most convenient indications of racial difference. (1) It is usual to attach considerable importance to the shape of the head: thus some heads are long, narrow, and high (almost 'gabled'), while others are shorter and broader. More precisely, attention is given to the **cephalic index,** i.e. the percentage ratio of the length to the breadth of the skull. Another feature is the volume of the brain-case (the **cranial capacity**); another is the degree in which the lower jaw projects (**prognathism**) and the angle it makes with the forehead; and another

is the shape of the nose. (2) Of some importance is the colour of the skin, that is to say, the amount of **melanin**, a darkish pigment that becomes deposited in the surface cells (see ANIMAL PIGMENTS). But by individual modifications the members of different races may come to have similar colour and texture of skin if they establish themselves in similar climates. (3) Another useful distinction refers to the hair, for there is plainly a great difference between the coarse straight hair of the Mongol and the woolly hair of the Negro. In some cases, just as in different kinds of mammals, there are interesting microscopic differences between the hairs of different human races, e.g. in the shape of the cross-section. (4) It is probable that human races differ from one another in the detailed functioning of their endocrinal system, that is to say, in their **ductless glands.** For these structures make the hormones which are distributed through the body by the blood, and are known to exert a potent influence on development and growth. Account may also be taken of average stature and of the nature of blood-fluid. Here it may be noted that even within one and the same race there are different 'blood-types.'

It is not suggested that differences in the hormones to which we have just referred can account for the *origin* of distinctive racial features, for these are almost certainly the outcome of **germinal variations.** But differences in the supply of hormones may account for differences in the degree of development attained by some of the deeply rooted constitutional peculiarities, e.g. in nose, lips, and hair.

It was maintained for a time by some investigators that the Negro race differed from others in the number of **chromosomes** in the nuclei of the body-cells; but this conclusion has not been substantiated.

If a white man spends half his lifetime working under a tropical sun he may become permanently tanned, the modification persisting even when he returns to Britain for his remaining years. There has been an unusual deposition of melanin in the surface layer of the skin, and the modification lasts even after the inducing conditions have ceased to operate. But it is very unlikely that any of the distinctive racial features have taken origin in this sort of way. As we have said, the likelihood is that racial characters arose as germinal variations, not as modifications. On the other hand, it is allowed by Weismann and by others who share his dissent from belief in the transmission of modifications or **acquired characters,** that deeply saturating climatic, nutritional, and habitudinal influences which may affect the body of the individual may also affect the germ-cells to the extent of provoking their variability. In short, a nurturally provoked germinal variation *may be* in the same general direction as a nurturally induced modification (see HEREDITY).

CLASSIFICATION OF RACES.—Within the single species *Homo*

sapiens it is usual to recognize a considerable number of distinct races, corresponding to the races of pigeons or poultry. But there has been much crossing of races since they first diverged from a common ancestral stock; and the problem of defining natural groups is very difficult. The one we give here is convenient and often used; but a grouping which recognizes a larger number of divisions is probably more satisfactory in the long run.

It must be understood that the definition of a **race** is based on anatomical and physiological identities, while that of a **nation** or **nationality** rests mainly on there being much that is common in the history of the people concerned. Thus the British nation includes more than one race.

Six great races are often recognized: Nordic, Alpine, Mediterranean, Mongol, Negro, and Australian. The first three are often grouped together as Caucasian or White.

The **Nordic** race includes many North Europeans, e.g. Scandinavians, Flemings, Dutch, many North Germans, some Russians, and some British.

The **Alpine** race includes European Alpines, like the Swiss, South Germans, Slavs, French, and North Italians. But it extends into Asia, including some mountaineering people of Persia and the Pamirs(?), besides some Armenians, Levantines, Mesopotamians, southern Arabians, and Jews,. The ancient Hittites are believed by many to have been allied to West Asiatic Armenoids.

The **Mediterranean** race includes most of the peoples of this region, e.g. some Semites, Berbers, Egyptians, Abyssinians, and other 'Hamites.' But many Semites (Arabs and Jews) are mixtures with Armenoid Alpines.

The **Mongol** race, the so-called 'Yellow Man,' shows well-defined characters, such as yellowish skin, coarse and straight hair, round head, flat face, and so-called slanting eyes. Here are included Chinese, Tibetans, Japanese, Koreans, Siberians, some Malays, and many others.

The **Negro** race includes the African Negroes and the Oceanic or Melanesian Negritos or Pygmies. Among the distinctive features may be noted the dark skin, the woolly hair, the thick lips, the broad nose. Bushmen are probably somewhat primitive Pygmies; and Hottentots are probably related to them, but stimulated to strong development by crossing with 'Hamites' or the like.

There remains, on this arrangement, the **Australian** race, which includes Australian natives, jungle tribes of southern India, and the Veddahs of Ceylon. They are characterized by black hair, which tends to be wavy or curly; by medium stature; by chocolate-brown, hairy skin; by long head, protrusive jaw, prominent eyebrow ridges, and flat retreating forehead.

CHAPTER IV

MAN AND ANIMALS

Man's diverse interrelations with the animal world—Our duty to animals—Feeding and breeding—Illustrations of useful animals—Domesticated reindeer in Canada—Man and his dog—Beneficial Insects—Honey from the honeycomb—Silk—Lac and lake—Alligator farms—Medicinal uses of animals—Utilization of the spoils of the sea—Animals that bite man's heel—Death-dealing Insects—Poisonous Fishes—Man's mistakes—Rats—The Grey Squirrel—The Musquash—Vanishing treasures—Man as conqueror of Insects—Trapping Tsetse Flies—Fighting against Moths—Aeroplanes and Locusts.

MAN'S DIVERSE INTERRELATIONS WITH THE ANIMAL WORLD

COMPARED with most living creatures, man is a new-comer on the earth, for even 'tentative men' did not emerge till about a million years ago. Nevertheless, man's interrelations with the animal world, and with the plant world as well, are extraordinarily numerous and intricate. The main reason for this is not far to seek, for man has distributed himself over all the earth; he has great adaptability to different conditions; when he pleases, or when he must, he is quick to seize opportunities of useful linkage or of strengthening his foothold; he is a born experimenter; and he is not afraid of living dangerously. Thus the circle of human life intersects a very large number of other circles; and of this we wish to give some illustrations, following in our preliminary survey an order suggested long ago by Sir Ray Lankester in a British Museum Report on Economic Zoology.

A SURVEY.—(1) EDIBLE ANIMALS.—First there are edible animals, one of the earliest of linkages. Deer and antelopes, rabbits and hares, pigeons and partridges, frogs and fishes, squids and snails, cockles and mussels, oysters and clams, crabs and lobsters, shrimps and prawns, locusts served with wild honey, juicy grubs from the palm trees, queen white ants for the Hottentots, palolo-worms for the Samoans, sea-cucumbers and sea-urchins for those who like them, and dried jelly-fishes for the Japanese. No doubt what is one man's meat may be another man's poison, but many kinds of animals are palatable in all the countries where they can be procured, and hunger is a piquant sauce available to all.

(2) ANIMAL PRODUCTS.—Second, there are those animals that furnish useful products, sometimes edible, though the animals them-

selves are not captured for the sake of food directly derived from their flesh. Here we have the baleen whales with whalebone plates and oil, the elephants with their ivory tusks, the wild asses whose skins make drum-heads, the beavers yielding the hats of long ago, scores of mammals supplying fur and hide. Birds' feathers serve for arrows and the angler's flies, for the savage's head-dress and the lady's hat. The crocodiles give us bags and the turtles combs; apart from their flesh, many fishes yield glue and fertilizers, and the livers of the cod and halibut supply the oil so precious for children. The cowries are for money, large oysters for mother-of-pearl, the giant *Tridacna* becomes a holy-water font, and the sea-snail's shell a sonorous trumpet. As for insects, the cantharid beetles make blisters for our skin, and the large blue butterflies make lovely decorations. It is interesting to visit a large Natural History Museum to get some picture of the variety of useful animal products; and the list is being added to every year.

(3) DOMESTICATED ANIMALS.—The third group is not a large one, but it is very important. It includes the animals that man has more or less domesticated because of their direct or indirect utility. Most of the important domestications, as of dog, horse, sheep, and cattle, were prehistoric, and we cannot do more than speculate in regard to the secret. Some kinds of animals were probably tamed when young, as with certain wolves; others were probably kept captive till they acquiesced. Over some it was utility that extended its shield; over others (totem animals) there was social, even religious, appreciation as well. Domestication appears to have been very unequal in different countries; thus there was none in Australia, and when America was discovered it had only the dog. This is very important because the domestication of animals had a great influence on civilization, as is evident in a case like cattle, which made settled husbandry possible.

Domestication implies a certain amount of taming—to this extent, at least, that the domesticated animal must not be aggressive or troublesome. It must show some plasticity and be able to remain in good health in conditions of semi-captivity. It must be willing and able to breed under control. But there are various grades of domestication, as the reindeer well illustrates.

We give a list of domesticated animals and of their most probable wild ancestors:

Dog, probably in great part derived from Studer's extinct Stone Age dog (*Canis putiatini*), which, in turn, probably sprang from a South European wolf. Some northern species of wolf and some jackals may have helped from time to time.

Cat, probably from the Egyptian wild cat (*Felis caffra*), possibly, but not probably, with some crossing with the intractable wild cat (*Felis catus*), still holding its own in Scotland and elsewhere.

Horse, probably from several tarpan-like wild horses of the Asiatic steppe country, probably of multiple origin, including, for instance, the African Barbary horse.

Ass, probably from the North African wild ass, perhaps with some help from Asiatic wild asses or onagers.

Cattle, of multiple origin, from various wild species, such as the European wild ox (*Bos primigenius*).

Sheep, probably from various wild species, such as moufflons, urials, and argalis.

Goat, from the wild goat (*Capra aegagrius*) of Persia and elsewhere.

Pig, the European forms mainly from the wild boar (*Sus scrofa*), but the Asiatic boar (*Sus vittatus*) probably helped.

Reindeer, from the wild species (*Rangifer tarandus*) in various degrees of domestication in the Old World (Lapps and Samoyeds), living wild in Scotland within historic times.

Pigeons, from the wild rock-dove (*Columba livia*), still found on some British cliffs.

Poultry, from the Indian jungle fowl (*Gallus bankiva*).

African ostrich, from the extant wild species, *Struthio camelus*.

Pheasant, from various wild species.

Turkey, from the American wild form, *Meleagris gallopavo*.

Goose, from the wild grey goose (*Anser anser*) of central and northern Europe.

Silk-moths (*Bombyx mori*), originally a wild species, probably at home in China or India, much changed in habits, e.g. of flight, by domestication, which began in remote ages.

Hive-bees (*Apis mellifica*), semi-domesticated, probably derived from a very variable Mediterranean species, originally quite wild, as it occasionally is to-day in various parts of the world.

As with cultivated plants, so with domesticated animals, there is in some cases much uncertainty in regard to the wild forms from which they were derived. This is particularly true of those races, e.g. cattle, that give indications of having had a multiple origin, from different wild species and at different times. Thus what we have said in our list is to be taken cautiously.

(4) **HELPING MAN'S OPERATIONS.**—Agriculture is one of the chief foundation-stones of the social edifice, and we can hardly think of agriculture apart from earthworms, which may therefore be taken as good representatives of those animals that favour man's operations. But much of agriculture is associated with the sowing of useful seeds, and the great majority of seeds depend for their individual origin on the pollinating insects that visit the flowers. For the potential seeds or ovules cannot normally become real seeds (embryoplants) unless the

egg-cell is fertilized by a nucleus from the pollen grain. Thus man owes much to the habitual pollinators, such as bees and butterflies.

Then we should also recognize the services of the scavengers that keep the earth clean, such as the sexton-beetles (q.v.) and the carrion-loving birds. When we think of the frequency of death, we sometimes wonder at the rarity of dead animals in woods and meadows and moorland; and while this is partly due to the fact that many of the animals that are killed are also devoured, we must not forget the scavengers.

(5) MAN'S DIRECT ENEMIES.—This group is dwindling, alike in numbers and in size, for man is in most cases a conqueror. But we have occasional reminders of the danger of the stronger beasts of prey, like lion and tiger; of the poisoners, especially certain snakes; of the giants, like crocodiles and pythons; of the voracious sharks; and of stinging creatures like hornets. More serious, however, are the parasites that invade man's body, like the hookworm and bilharzia, or are swallowed with imperfectly cooked food, like the young stages of tapeworms, or with contaminated water and so on. But worst of all are the invisible microbic animals, too small to be seen, like those Protozoa that cause malaria and sleeping sickness. The serpent that still bites the heel of insurgent man is nowadays usually of microscopic dimensions. And even these are being successfully countered.

(6) INDIRECTLY INJURIOUS.—The sixth group includes those animals that are injurious to man's crops and stock, and thus *indirectly* injurious to man. Plagues of voles are still of occasional occurrence, and as the appetite of these little rodents extends to almost every kind of plant, they turn farms into desert land. The sparrows may be a pest; the locusts that devour every green thing are still a menace. Injurious insects are legion, e.g. wireworms, cotton-weevils, wheat-midges, warble-flies, sheep bot-flies, cockchafers, and the *Phylloxera* of the vineyards. Many threadworms are serious parasites of both plants and animals; the liver-fluke destroys many sheep; tapeworms often kill the playful lambs, and the stagger-worm is sometimes fatal among the survivors.

In some cases man plays into the hands of his indirect enemies: thus the gradual extension of potato-fields, from west to east across the United States, gave the Colorado beetle a non-natural opportunity for prodigious increase. Sometimes, however, he deserves our admiration for the ingenuity with which he sets a thief to catch a thief, e.g. in importing a new insect to check another which has intruded disastrously.

(7) DESTRUCTIVE TO STORES.—A seventh group may be convenient for those animals that are destructive to stores and to man's property in general. Rats and mice destroy stores of food, and they spoil much more than they eat. In warm countries the white ants or termites have an extraordinary appetite for everything wooden

and for much more besides. Their dry-as-dust food includes books. The destructiveness of the small caterpillars of clothes-moths is well known, and the 'worm-eating' of furniture is due to the grubs of the death-watch beetle and allied forms. Even the well-guarded honeycomb in the hive is not always safe from insect intruders. Of great practical importance are the weevils and other beetles that feed on stored corn, and the larvae of flour-moths, that attack even hard biscuits.

(8) INDIRECT FRIENDS.—Our final group is on the credit side, for it consists of those animals that check groups 5, 6, and 7. Thus weasels may check voles, and owls may check mice. The hedgehog thins the ranks of the slugs, and the mole devours many injurious insects in the soil—a useful service to be set against its appetite for earthworms. Water-wagtails are fond of the little freshwater snail that cradles the larvae of the liver-fluke, and the lapwing does much good in destroying wireworms and leather-jackets. Spiders are useful in snaring many insects that are injurious, but they occasionally catch some flies that are useful. The lady-birds help to keep down the prolific aphids, and the mother ichneumon-fly lays her eggs in caterpillars which the hatched larvae devour.

SUMMARY.—Man is part of a changeful web of life, in the fashioning of which he shares. More and more, however, he is keeping a keen eye on the indirect, as well as the direct, results of the changes he brings about. The success of his weaving depends on his understanding.

Our Duty to Animals

As we have said, man's first relation with the larger beasts of the field was one of direct **competition** in the struggle for existence. He had to pit brains against brawn, and it was a profitable rivalry for him. It is still his duty to keep predatory animals in check, but, as we have just remarked, the snake that bites the heel of evolving man is rapidly verging on the microscopical. Yet when villagers unite against a 'man-eater' lion, the old direct struggle survives, and every one approves. Similarly, when beasts of prey need thinning, and the chase tests courage and endurance, when the animals hunted are really wild and the shooting is really good, when the social issue is clear and pheasants are not preferred to peasants, we need not waste indignation over sport. Fox hunting at least keeps the fox alive in Britain, and a sportsman is seldom cruel. Sometimes, however, the pursuit of 'big game,' or the striving after 'big bags,' brings sport down to the level of a luxury-reversion, a fictitious harking back to primitive ways for the sake of notoriety or thrill.

Thus it is impossible to justify the shooting of nineteen gorillas on a recent African expedition. In the old days of direct conflict with wild beasts primitive man had a sporting admiration for his antagonist, as we see in his girdle of lion's canines, his spirited drawings on the walls of the cave, and his choice of totem animals which embodied desirable qualities. This is important, for if there is no admiration for the wild creature, there can be nothing but a prosaic attitude. He loveth well who knoweth well. If you know your otter you can never be cruel to it, though you may possibly kill it.

After the ages of direct competition came the times of **domestication,** to which we have referred elsewhere in this book, and perhaps man was not far from his best in the taming of a wolf into a dog. It is a lost art, implying patience, sympathy, and insight—making friends with animals, young ones to begin with. To some of these man gave intellectual encouragement, making them true partners, as in the case of dog and horse. As regards other types, such as sheep, he rather traded on their docility and repressibility. A third set, like cat and ostrich, accepted his aegis, without surrendering much of their wildness. Man's relations with domestic animals have not always been commendable, for he has sometimes smothered a creature's personality in his eagerness to reach some utilitarian result; thus he has overfattened the pig and often depressed the donkey. Yet on the whole the attitude of normal man, neither careless, uncontrolled, nor niggardly, has been wholesome. He has said: I have taken this creature from the wild into my kingdom, into co-operation; I am responsible for it, according to my lights. It is not merely my possession, I have adopted it; and part of myself has gone out into it. Love me, love my dog; hit my dog, hit me. We have come through much bad weather together; we have mutual respect. The look of loyalty, love, and trust in the dog's eyes seals the compact. The linkage becomes ethical.

After domestication came **exploitation,** often a sad chapter, for man has exterminated much and made the world at once less interesting and less beautiful. We must distinguish the gradual and inevitable retreat of wild life before agriculture from the greedy and often ruthless extermination of valuable creatures such as sea-otters, baleen whales, and some of the birds of paradise. It is man's duty to conserve the higher forms of life, and although the number of species in Britain has not decreased under man's régime, it is a poor exchange to have got rats instead of beavers, and cockroaches instead of reindeer. Sometimes the extermination is actually cruel, as in the case of egrets that are shot at the nesting time.

But are we not to destroy rats and reduce the flocks of sparrows? Surely, but many of these plagues are due to careless disposal of

'crumbs' and to shooting down of natural enemies. Are we not to have beautiful furs? Surely, if we are worthy of them, yet the purchase of very costly ones usually means that we share in the impoverishment of the world. It must be allowed that a sea-otter coat or a kiwi cloak is quite illegitimate. While there are many fur animals that can still stand thinning, perhaps the cleanest way out is along the line suggested by silver-fox farms and ostrich-rearing.

A fourth attitude is quite modern, and may be described as scientific **conservation.** The duty of preserving ancient treasures has become vivid to many minds. Man is a trustee of animal life. Every one knows that many animals have a unique scientific interest, and that if they are lost they are irreplaceable. Some are antiques like the giant tortoises of the Galapagos Islands, and there is an impiety in obliterating ancient milestones. Some animals reveal secrets, as the New Zealand lizard disclosed the story of the pineal eye, and the spectral tarsier the trend of brain evolution towards man; and there is an impiety in defacing our own history. Others, again, like the osprey, are simply masterpieces, and there is impiety in destroying great works of art. But a second reason that strengthens the hands of scientific conservation is the importance of preserving the Balance of Nature. Many creatures, often humble ones, are wrapped up in the bundle of life with ourselves. Their threads enter into our web, often in very subtle ways. And careless introduction may be as disastrous as ruthless elimination.

But fifthly, there is an attitude even more humane than that of scientific conservation; it is **the evolutionist attitude.** These creatures are our kin. In a new sense we can say to the worm: 'Thou art my mother and my sister.' With Emerson we may see the worm 'mount through all the spires of form, striving to be man.' We are solidary with the rest of creation, which once included our ancestors. These animals are distant collaterals of the human stock, our remote relatives, to be cruel to whom is a self-contradiction. These animals are sub-personalities, sharing with us the mystery of life and mind. They are expressions, even as we are, of the august Will. To drop to the severely concrete, it is not difficult to understand why a recent explorer confessed that 'no one with a spark of feeling can free himself from the thought that killing gorillas is akin to murder.' We like what was said of one of the most famous of French scholars, that he could not be discourteous, even to a dog. Our duty is expressed in Wordsworth's lines:

Never to blend our pleasure or our pride
With sorrow of the meanest thing that feels.

In conclusion, we feel strongly that the modern movement away from cruelty and carelessness is a robust one. We are trustees of a

rich heritage in Animate Nature—plants as well as animals—a Nature that is accompanying us on our evolutionary journey. We must control, but we must also conserve—always giving the preference to the higher expressions of life. When elimination is inevitable, we should try to establish sanctuaries and reservation tracts. When we kill, we should do it as quickly and humanely as possible; when we utilize, we should not treat the creature woodenly; it is a sub-personality. When we experiment, it should be effected, as it generally is, with a very sensitive conscience. We do not know much about the pain that animals feel, so we should proceed cautiously, and the greater emphasis should perhaps be laid on the harm we do ourselves if we are wittingly cruel. To hurt an animal's body may matter less than the violation of our moral self. In any case, are we not all agreed that we shall extend our humanity to a wider kinship in proportion as we become more humane to one another?

Feeding and Breeding

A very important question for man is how to make the most of domestic animals. Part of the answer is in the two words, 'feeding' and 'breeding': two great pivots of life. The rearer of stock two centuries ago was rarely such a fool as to think that the more food his animals got the better they would be. But it is a far cry from a recognition of the value of moderation to the modern scientific rationing. For much thought is now given to working out a regimen for cattle comparable to that now prescribed for men by the experts on human diet. The scientific rationing must take account (1) of the animal's capacity, not for eating, but for coping digestively with its food; (2) of the amount required, measured in calories, to keep the creature in good health; and (3) of what should be allowed in view of what the animal is going to be or do. This is an inquiry of the highest importance.

MINERAL CONSTITUENTS.—One of the difficulties seems to be that animals require a balanced amount of *mineral*, as contrasted with *carbonaceous*, constituents in their food. This has been particularly studied at the Rowett Institute, near Aberdeen; and though it is too soon to be very positive, we may say that the conclusion towards which the experiments are pointing is that the first requirement of life and health is the maintenance in the blood and tissues of ten or twelve essential inorganic elements in the proper amounts and proportions. An animal fed on food free from minerals dies sooner than one in complete starvation, and dies in acute bodily distress; for the balance of mineral constituents is necessary, not only for the continuance of positive health, but also for the avoidance of certain diseases. It is

plain that the necessity for regulating the mineral balance increases in proportion to the restricted and artificial nature of the food that the animal gets.

VITAMINS.—When stock animals are getting plenty of naturally vitalized food, such as grass, the vitamins, or accessory food substances, will look after themselves, so to speak. But it may be very different when the food is artificial and restricted in range. Then, the lack of vitamins may make itself severely felt. There seems to be a noteworthy difference of opinion in regard to these vitamins (q.v.), which are sometimes too much like hypotheses invented to explain certain phenomena, but there are some reliable facts. The presence or absence of a certain vitamin in the ration of pigs may make all the difference between health and sickness. 'Rats lived and grew on the butter from grass-fed cows, but degenerated on the butter from cows which were equally healthy, but were being fed on a diet deficient in one of the vitamins. The addition of a small dose of cod-liver oil to this ration was sufficient to increase the vitamin content of the butter tenfold.'

Along with feeding we may refer to the demonstrated value of ultra-violet irradiation for certain animals. This is a young inquiry, but experiments indicate that, if a food ration is ill balanced as regards minerals, the irradiation may bring about an adjustment. It is too soon to say *how*.

ULTRA-VIOLET RAYS FOR COWS—When electricity becomes more generally available, it may be found profitable to irradiate, not merely poultry, but milch-cows during the winter months. The recent experiments at the London Zoo, not to speak of the supreme experiments with children, show the invigorating value of the ultra-violet rays. In any case, those who are inclined to be very cautious—the scientific pace is at present almost dangerously rapid—will return with satisfaction to the old-fashioned appreciation of ordinary sunlight.

Working patiently for centuries, watching alertly for promising new departures to crop up, coupling similar desirables together, and always sifting rigorously, the older breeders, dating from prehistoric times, have achieved veritable wonders—the origins of the fine domesticated races that form part of their legacy to modern man. When we think of such achievements as the thoroughbred horse, we cannot be surprised that the young science of heredity or genetics has not yet been able to contribute results of startling importance.

MENDELIAN BREEDING.—We know, however, that this science has given the art of breeding a *new method* by which advances can be made more securely and more rapidly than before. Does the breeder wish for more fertile hens or is he content to ask for them without yellow legs and yellow skin, the Mendelian expert will come to his aid. And

so it is with weight and pattern in rabbits, with fleece-characters in sheep, with milk-yield in cattle, and so on through a lengthy list.

There are many other lines of inquiry that are being followed nowadays with success—all leading or pointing towards the improvement of our domesticated animals, improvement meaning in this case increased usefulness to man. Thus there are the awesome inquiries into the physiology of reproduction and sex, sometimes leading to a repunctuation of the animal's life by injections of potent hormones. There is the steady approach to a practical determination of the sex of the offspring. Very creditable is the unravelling of the intricate life-histories of some of the important parasites of animals. Outstanding is the increasing power of balking disease in domesticated stock.

We return to Herbert Spencer's saying: 'Life is not for science, but science is for life.'

Illustrations of Man's Relations with Animals

Following our adopted plan, we pass now from the general survey of man's relations with animals to give a few concrete examples in a somewhat lighter vein. We begin with a few instances of *the directly useful.*

Domesticated Reindeer in Canada

One of man's lasting problems is to make the most of useful animals, and the importance of this increases as the world becomes more and more densely peopled. A recent attempt to make more of the **reindeer** or **caribou** in the great north plains of Canada is full of interest, practically and biologically. The experiment is still in its early stages, and no one can predict the outcome; but the prospects are good. We follow a vivid recent study by Mr. O. S. Finnie.

The area concerned is an immense one—the northern part of Canada from Alaska to Hudson Bay, nearly two-fifths of the total area of the Dominion, and covering (including its non-tidal waters) about one and a half million square miles. The term Barren Grounds often applied to the northern plains is not a good one, since more than half a million square miles of sub-Arctic forest are included.

When first explored, these plains were teeming with caribou or Arctic reindeer (*Rangifer arcticus*), just like the reindeer of north Europe and Asia. In days before fire-arms the caribou hunt used to be very laborious, but the rifle has made it too easy, and the numbers have been greatly reduced. Apart from shooting there has been a heavy mortality due to a diverting of the old migratory routes, e.g. to the Arctic islands before the fawning season, for this change has

increased the exposure of the caribou to the attacks of carnivores and of injurious insects. Thus the Government, through the Department of the Interior, has of recent years been tackling the problem of conservation on the one hand and of domestication on the other, both in the hope of lessening the severity of the human struggle for existence. It must be understood that reindeer can thrive on lichens and dwarf vegetation in many a place where cattle would starve, and that the animal is in other ways admirably adapted to the conditions of the far north.

Thus we may recall, just as an example, the spreading hoofs, with sharp cup-shaped edges, which give the deer a firm foothold on yielding hummocky ground in summer and on snow and ice in winter. In his *Wild Animals of North America*, Mr. E. W. Nelson describes the extraordinary deposit of 'back-fat'—a layer of pure tallow which extends along the back from the shoulders to the rump, gradually thickening until it is four to six inches in depth. This slab of tallow serves as a store, which is burnt away in the hard winter, keeping up the supply of animal heat. It is much appreciated as food by the Eskimos and Indians, to whom the caribou means so much for sustenance and clothing, and also for transport.

For fifteen centuries or more there has been a semi-domestication of reindeer in the Arctic regions of the Old World, and it was on these stocks that the Government drew in effecting introductions into Canada. Between 1892 and 1902, 1,580 reindeer were imported from Siberia and 144 from Lapland, and the result was a great success, all the more when some Laplanders accompanied their beasts to show the Eskimos of Alaska how to treat them. From the nucleus introduced into Alaska in the ten years referred to, there have arisen about 750,000 deer, besides the 200,000 or so killed for food and hides. Dr. Hornaday writes encouragingly: 'On the whole, the systematic introduction of reindeer along the north-west coast of Alaska—now almost barren of wild life fit for human food—is one of the most humane and sensible measures ever undertaken for the children of the cold. If this industry is further fostered and diligently pursued, its ultimate value in the promotion of the moral and material welfare of the Eskimo is beyond calculation. The multiplication of the herds in the hands of private owners means a great increase in the animal food-supply, less dependence upon the foods of civilization, a greater measure of general prosperity and contentment, and in the end far less expense to the Government in the form of annual maintenance for starving natives.'

Now the point is that this experiment has been continued with very encouraging results, and we must all have read how Dr. Grenfell has succeeded in extending it to Labrador. What is now being tried

in Canada is the transference of large numbers of caribou from Alaska to the North-west Territories, to areas where the pasture conditions are promising. The driving of thousands of deer from Alaska towards the Mackenzie delta has proved a very difficult task, owing to the breaking away of parts of the herd in obedience to their homing instinct, but it is being patiently effected. More patience will then be needed to train the young Eskimos to become herdsmen, not hunters. Mr. Finnie's conclusion is of great interest: 'It is still premature to foretell the possible outcome of the undertaking,' but it is no fool's experiment. 'It may be safely assumed that Arctic Canada has room for millions of domesticated reindeer in areas where, due to the severity of climate and inferiority of soil, other forms of agricultural development are at present out of the question, and where the country, aside from mineral possibilities and as a fur-producer, would otherwise be unproductive.' Of course the aspect of the problem that appeals to us at home is *not* the production of more food; but surely there are lessons, of plasticity and patience at least, to be learned from the great Canadian experiment.

Man and His Dog

The first animal to be domesticated by prehistoric man was the dog, and this great event seems to have occurred in the Neolithic Age, when stone weapons were still in use, though finer ones than before.

We do not know with any certainty how often man effected the transformation from wolf to dog, or how many wild species of the genus *Canis* were used in different places, or whether dogs arose from grey jackals and wolf-jackals as well as from wolves. It is likely that the first step in domestication was taken when the hunter brought some orphaned wolf-cubs home for his children to play with. The rest was due to thousands of years of careful sifting and breeding among the new departures that are always cropping up in the changeful canine race.

Amid many uncertainties it is certain that dogs evolved from wolves; and that there were several different kinds of prehistoric domesticated or semi-domesticated dogs in Europe, as their remains in Stone Age settlements show (p. 1340). One of these was the 'peat dog' (*Canis palustris*), found near Neolithic lake-dwellings in Switzerland, probably ancestral to Scotch terriers and the beautiful, sometimes snow-white, Siberian dogs.

Another was the 'intermediate dog' (*Canis intermedius*), believed to be ancestral to hunting dogs that followed by scent, such as fox-hounds. A third bears the quaint, but rather fine, name of 'best-

mother dog' (*Canis matris optimae*), with remains in Bronze Age stations. It leads on to old-fashioned forms like the Belgian sheep-dog, and onwards to finer races like the Alsatian and the collie.

But we must refrain from dogmatism, for the canine pedigree seems to be a tangle; moreover, we have received convincing evidence that even to-day dogs may occasionally pair with wolves and have fertile offspring. The view we are indicating here is based on the well-reasoned discussion of the data by Dr. Otto Antonius in his German book on *Domesticated Animals* (1924).

Why has the dog done so well, developing one good quality after another—courage and affection, intelligence and reliability, strength and swiftness? How has it evolved along paths which the cat will not tread? Why didn't man domesticate the fox? How is it that the dog has given rise to so many different types—collies, spaniels, setters, terriers, bulldogs, poodles, bloodhounds, St. Bernards, and many more?

The success of the dog has been primarily due to pre-domestication qualitys. Fine brains, keen senses, a strong heart, and a lithe body we cannot lay stress on, for they are shared by many carnivores, such as the fox and the otter. Unless we are mistaken, the special quality that predestined a wolf to become a dog was its combination of two antithetic ways of living—the each-for-himself policy, and the self-subordinating instinct of the pack.

For many of the wolves are individualists in summer and gregarious in winter, thus learning in two great schools of life, each excellent in its way. In relation to the solitary or monogamous life of summer the wolf has evolved all-roundness, self-reliance, and independence; and it is also to be noted that the wolf's family life may last beyond the breeding season, and that the playful cubs receive education from their parents.

On the other side, in relation to the gregarious or social pack life of winter, the wolf has evolved self-subordination, loyalty, and the great art of playing the game.

The importance of the call, whence evolved the bark, is of course greater during the pack period. There seems to us genuine insight in the suggestion made by Benjamin Kidd that the dog accepted and still accepts man as a sort of super-leader of a pack. The cat, walking alone, could never have become man's ally as the dog has done.

When one thinks of it, man has not had an entirely progressive influence on his domesticated animals. Though the lambs still rebel, the sheep are servile and stupid; chicks are experimenters, but hens show the arresting influence of a sheltered life; cattle have fine brains, but in most countries the field generally remains fallow.

But in the case of the dog it has been entirely different, for man

has usually, though not always, selected and fostered variations in the direction of intelligence. In early days especially, when there were few 'luxury dogs,' man gave the dog, like the horse, the inestimable boon of responsibility. He made the dog his partner, gave it things to do that really mattered, and rewarded or punished it in direct reference to faithfulness. He has selected and eliminated, bred and fostered in relation to educability and reliability. The sieve has been a fine one—the dog's ability to be man's intelligent and loyal partner; and that is the chief reason why there are so many finely tempered dogs to-day—some rising to heroism.

Beneficial Insects

We are perhaps too apt to think of insects with a frown. They are so destructive to crops and stores; they are the vehicles of so many diseases, such as malaria and sleeping sickness; not a few are troublesome parasites, such as warble-flies and bot-flies; and most of them are so prolific that they might soon smother all other living creatures, if they did not turn on one another, and if they were not kept in check by birds and bad weather. Now this frowning at insects is not unreasonable, and the damage they do is a useful warning against thoughtless or short-sighted disturbances of the Balance of Nature. Yet we should at times correct our partial outlook by remembering the sweetness of honey—especially in the honeycomb, and the softness of silk—especially when it comes from a silkworm. And besides other useful things that insects make, we should remember that the linkage between flowering plants and their insect-visitors is the most important interrelation in the world, for it secures in the majority of cases that cross-pollination which increases both the quantity and the quality of the fertile seed. It is hardly magnanimous to dwell on clothes-moths and potato-beetles, and to forget that insects have played a notable part in the evolution of flowers. Nor should we forget that in an alimentary sense insects are always turning into birds—entering upon another avatar at a higher level. But, coming down to a matter-of-fact question, let us take a brief survey of the beneficial insects as far as agriculture in the wide sense is concerned. No doubt this has often been done before, but we have short memories. Who are the farmer's insect-friends? First, there are the reddish or yellowish **ladybirds** (*Coccinella*), most charming of little beetles, which do much good by devouring aphids or green-flies, which are altogether to the bad. But it is a pity that we have not a more precise acquaintance with the unprepossessing blackish grubs, whose appetite is such that one grub can eat three dozen aphids without stopping. They emerge from eggs which the mother ladybird lays in small groups on

the stem or under the leaves of a plant that is infested with aphids. She may not be intelligent, but she behaves as if she were—with an unconscious prevision difficult to understand.

Second, there are the **ichneumon-flies** (*Rhyssa persuasoria*), in the same order (*Hymenoptera*) as saw-flies, wasps, and bees. They are perhaps our best friends, best in the sense of being most effective in warding off the disaster of over-population among injurious insects. They are active aggressive creatures, of all sizes from that of a capital on this page up to that of a hornet; and their peculiar trick is to lay their eggs in the young stages of other insects. Within these the ichneumon-grubs develop and proceed to devour their shelter. No doubt they destroy many useful insects, but against this there has to be weighed the fact that they attack and destroy most of the many grubs and caterpillars of insects that damage our crops. Not only do the larvae make sure work of their victims, which they devour from within like internal beasts of prey, but they are themselves in relative safety all the time. As for the adults, they can look after themselves.

Lacewing-flies (*Hemerobiidae* and *Chrysopidae*) deserve a prominent place, for they are as useful as they are beautiful. Many are fascinating, with their delicacy of build, their green colour, and their golden eyes. The lace-like wings, which indicate some relationship with dragon-flies, are longer than the body, and when at rest are carried flat against the sides. The eggs are laid in groups, and each is borne on the end of a long hair-like stalk. From the eggs there emerge dark brown grubs, which often mask themselves with little pieces of lichen or bark or with the empty husks of their victims. They have a great appetite for aphids and scale insects, and are altogether to the good.

Some of the **hover-flies** or *Syrphidae*, which we often see hovering and darting and settling in the garden on a sunny day, deserve honourable mention, for their larvae devour aphids. The flies are somewhat bee-like or wasp-like, but they are two-winged *Diptera*; and the dirty-white or greenish larvae are maggots. Also among the beneficial *Diptera* are the house-fly-like *Tachinidae*, which lay their eggs on or near caterpillars and grubs. These the maggots eventually devour in ichneumon fashion. Such are a few of the beneficial insects.

HONEY FROM THE HONEYCOMB.—Honey is transformed nectar, and nectar is a solution of an overflow of the sugar that green plants make in their everyday industry which we call photosynthesis (see INDEX). Nectar is built up from carbon dioxide and water, which are turned into sugar and oxygen by sunlight and protoplasm working together, in the presence of the green compound called chlorophyll (q.v.). Professor

E. C. C. Baly's investigations suggest, however, that we need not say very much about the part played by the living matter or protoplasm. For the wonderful transformation may go on in experimental conditions, in the absence of the chief of the magicians—called Life.

In any case, the nectar is there in the plant—an exudation that attracts insects to visit the flowers and thus effect cross-pollination. It is true that nectar may also overflow from *extra*-floral nectaries, but floral nectaries are more frequent and more profitable, for they bring the insect-visitors to the right place. When fertilization has been effected and the nectaries close, the surplus sugar can be diverted in to the swelling fruit.

Bees are not the only creatures that appreciate nectar, for some of the ants become animated honey-pots, hanging from the roof of their house like bunches of yellow grapes. Some birds, like hummers, are very fond of the more fluid kinds of nectar; and an occasional sweet-toothed wasp may point the way that the ancestors of bees followed long ago when they ceased to be carnivorous and became predominantly honey-eaters.

Nectar consists for the most part of cane-sugar (sucrose), and in the bee's honey-sac—a globular part of the food-canal between the gullet and the stomach—this is changed by the ferment of the salivary glands into grape-sugar (glucose) and fruit-sugar (fructose). But honey contains more than these substances; it includes an unchanged residue of cane-sugar, a little mucilage, and more than a little water, some wax and essential oils, a trace of pigment and salts, besides grains of pollen which contain protein material. So honey is much more than sugar; it is a delicate mixture of foodstuffs; it is an elixir that keeps one healthy, especially when one gets it from the honeycomb, and that from beekeepers who do not feed their bees in the summer-time. They say that honey makes people young again, or, at any rate, that it prolongs youth and staves off ageing. It certainly has many virtues. What better can one do, then, than take to eating honey, like the long-lived queen in her parlour? But there is one thing better, we believe, and that is to keep the bees whose honey we eat.

The best honey is 'virgin honey,' made by bees that have not swarmed. It is stored in pure-white cells of translucent wax. Later on in the life of the hive the honey may have to be stored in cells that have been already used as cradles for grubs, and these have darker and thicker walls. It is delicious honey still, but not quite so fine, and the older comb is not so inviting. These incidental differences disappear when the honey is removed from the comb by the old-fashioned dripping, or by the modern centrifugal extractor. We are assured that this extracted and pooled honey is the best of

all; but the honey from the honeycomb is more interesting to eat, and one cannot help suspecting that there may be a loss of some subtle accessory factor when the honey is removed from its natural cups. In any case there is a gustatory pleasure in breaking the waxen walls in one's mouth.

Biologically considered, honey has three aspects very familiar to us all. Primarily, along with pollen, it is the bee's food. Some of it passes from the honey-sac through a complex combination of valve and sieve into the digestive stomach, and it is said that if solid particles like pollen grains have passed through, they cannot return in the process of **regurgitation**—the process of passing the honey from the honey-sac into the honeycomb. Secondly, along with pollen, it is part of the food given to the grubs after they have had some gastric education by means of more digestible milky material which seems to be mainly a secretion. Many insects feed their offspring by regurgitation. Thirdly, the honey, with all that in it is, forms a store for the winter—a store that man steals. It is this storing of honey that accounts for the continued persistence of the beehive, in contrast, for instance, to a wasp-community in which only the young queens survive the winter. Much of the stored honey goes to meet demands from day to day, but there is a large surplus which is characteristic of honey-bees and makes *a permanent community* possible. Honey is wealth—that is to say, stored energy. The hive illustrates the value of capital as well as of labour.

The sheets of honeycomb are vertical, and the cells are arranged on the two sides. They are not quite horizontal, but tipped a little upwards, so that the viscous honey does not so readily stream out. But there is another reason for the retention of the honey—it becomes gradually thicker by the evaporation of water-vapour. Thus nectar with 80 per cent of water may become honey with 25 per cent. But it may be noticed that some nectars, like that of the fuchsia, are very dense to start with. An interesting point in regard to the ripening of honey in the comb, where the changing from cane-sugar into grape- and fruit-sugars seems to continue, is that the ventilation which the bees effect by fanning with their wings not only keeps the hive from becoming stuffy, but drives away water-vapour and thus thickens what is stored.

NATURAL HISTORY OF SILK.—Every one knows that all the silk in the world—real silk, as distinguished from the artificial product so largely used to-day—is due to the work of the 'silkworm,' the caterpillar of an insignificant-looking white moth, *Bombyx mori*. Many other caterpillars produce silk, but this species is the domesticated form, and all the finest silk in the world is procured from its cocoons. Other silk-producing caterpillars are known as 'wild' forms, and

among them there are several of practical importance. We need only refer to an oak-feeding species in Japan, used in making a special fabric now known as Jap silk, and another, also oak-feeding, in China, from the cocoons of which is made the much-used and very durable material called tussore silk.

The origin of silkworm-rearing and silk-weaving as an industry is lost in the mists of antiquity. Legend has it that silkworms were known in China 2,000 years before Christ, and that the Chinese empresses and their ladies-in-waiting devoted themselves to the care of the insects and the reeling of the cocoons—two delicate operations that have always been considered specially suitable for women. A Chinese empress, too, is credited with the invention of the hand-loom. For many centuries, it seems, the Chinese guarded their secret with the greatest care. But it leaked out; and it is an historical fact that silken tissues formed an important article of commerce among Eastern nations before the beginning of the Christian era.

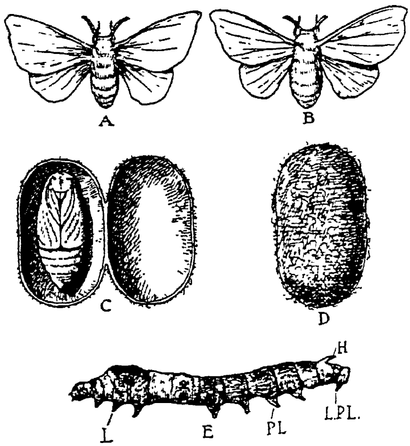


FIG. 462. STAGES IN LIFE-HISTORY OF SILK-MOTH (*Bombyx mori*)

A and B, male and female adults. C, pupa lying within cocoon. D, cocoon. E, caterpillar with three pairs of true legs (L), five pairs of pro-legs (PL and L.PL), and dorsal 'horn' (H).

The lore of silkworms and silk-making did not reach Europe until the sixth century A.D., when two Persian monks, who had been missionaries in China, came to the Emperor Justinian and told him what they had seen of silk culture. The emperor, quick to perceive the advantage of such an industry to his own kingdom, persuaded the monks to return to China and bring back some of the eggs. These were brought to Constantinople concealed inside bamboo canes, and soon the industry was firmly established in the neighbourhood of that city. It remained a monopoly there for a long time, but by the twelfth century it had spread to many other countries and taken a firm hold, especially in Italy and France, in both of which it was carefully fostered by the Government. Repeated attempts were made to introduce it into Britain, but these failed for various reasons, chiefly connected with food and climate. America was only a little more successful. Both countries, however, have taken a large share in manufacture from the raw material.

The silkworm feeds almost exclusively on the leaves of the white mulberry tree (*Morus alba*). It can be reared on the black mulberry and even on lettuce, but on neither of these foods does it give such a good result in silk. The twigs and leaves of the food-plant are brought into the rearing-sheds or rooms, and supplied to the caterpillars fresh every day. The caterpillar when hatched is only about a quarter of an inch in length; it feeds heartily and grows rapidly until the time of the first moult, when it slacks off for a little. Four moults take place before the caterpillar is ready to spin; the fifth and last moult occurs within the cocoon.

The 'silk' is a viscous fluid secreted by a pair of long tube-like glands which lie along the sides of the body, becoming very thin towards the head end, and opening by two minute pores on the underside of the third pair of mouth-parts, known as the labium or lower lip. After the fourth moult these tubes enlarge greatly, and are clearly visible through the thin chitinous cuticle. The fluid oozes out at the two pores, and hardens immediately when it comes into contact with the air, the two streams joining to make a single thread. The caterpillar, now three inches in length, is ready to spin its cocoon —an extraordinarily interesting performance.

Writing about a century ago in *Le Spectacle de la Nature*, the Abbé de la Pluche gave an admirable description of the whole process as he himself observed it. He repeatedly removed the loose overhead canopy among the twigs, which is the invariable first step in the work, for, 'Nature having ordained silkworms to work under trees, they never change their method, even when they are reared in our houses. When at last the caterpillar became tired of beginning again it fastened its threads to the first thing it encountered, and began to spin very regularly in my presence, bending its head up and down and crossing to every side. It soon confined its movements to a very contracted space, and by degrees entirely surrounded itself with silk, and the remainder of its movements became invisible, though these may be understood by examining the work after it is finished. . . . After building her cocoon she divests herself of her final skin, and is transformed into a chrysalid, and subsequently into a moth, when, without saw or centre-bit, she makes her way through the shell, the silk, and the floss.'

But the silk-rearer is not so patient as the Abbé was. He does not wait for the *dénouement*. The outer covering is loose and roughly arranged, but the inner lining is fine, pure silk, and when the movements inside the cocoon cease, the cultivator knows that the spinning is finished. The cocoons are about the size and shape of a pigeon's egg, those of the female slightly larger than those of the male—though it is rather premature to speak of sex at this stage. As many of each

sex as are needed for carrying on the stock are chosen and placed on strips of linen in a darkened spot. The moths will hatch out, and will mate, but they will not fly away. The females will drop their eggs on the linen and will speedily die, and the same Nemesis of reproduction befalls the males. But this segregation for breeding purposes is only for the elect; all the rest are killed right away.

The cocoons are placed in warm water, or more often in a steam-heated chamber, to kill the larvae. They are then emptied of their contents, and soaked in warm water to dissolve the gum about the thread and lining the cocoon. They are stirred gently about in the water with brushes of fine twigs until the ends of the threads float out and are caught. Each cocoon yields about 300 yards of thread, and five to eight threads are unwound and 'reeled' together to form the 'raw silk' of commerce. The waste silk or floss from the outer envelopes, and the silk from broken cocoons, cannot be reeled but are made into yarn; and under the name of 'spun silk' this is put to many uses.

Man's adoption of the silkworms as domesticated animals has not been altogether to their advantage. They are well fed and cared for, it is true, and they are protected from the ravages of hungry birds and insects. But the moths have almost lost the power of flight, and the caterpillars have become so stupid that they cannot find the way to their own food unless it is put before them. If one of them falls off the twig on which it has been placed, it simply lies helpless, instead of climbing up the stem as any wild caterpillar would do. Worst of all, they have in great part lost the power of resistance to disease that all really wild creatures possess, and they are liable to many epidemics.

In 1849 the silkworm disease known as *pébrine* became very widespread, and thousands of French peasant families were threatened with ruin through its ravages. All sorts of measures were tried, such as bringing eggs from other countries and introducing 'wild' stock to interbreed, but these met with only temporary success. Pasteur was called in to help, and it is one of the many debts the world owes to that great investigator that he discovered the cause to be a micro-organism—a *Protozoön* we now know as *Nosema bombycis*—and devised means by which it could be combated. His method was the drastic one now being pursued in regard to foot-and-mouth disease in cattle—the infected animals were sternly destroyed. When the silk-moth had laid its eggs it was crushed, and the débris of the body was searched for the *pébrine* germs. If these were found, the eggs were likewise destroyed, and thus the method worked back along lines which Plato called the purgation of the race. Unfortunately Pasteur's purgation did not amount to eradication of the disease, for the parasite is harboured by other insects which are not under

man's control; and here it may be recalled that one of the species of *Nosema* is one of the parasites of our hive-bees. Nevertheless Pasteur's drastic method was a practical way out, and he not only saved France more than the cost of the Franco-Prussian indemnity—strangely small it seems in these days!—but kept a useful industry alive, and, best of all, convinced the world dramatically of the far-reaching possibilities of the biological control of life.

LAC AND LAKE.—The world is strewn with Natural History romances, and there is one clinging to a stick of red sealing-wax—the romance of **lac.** Perhaps it is less disguised in the pretty little red lacquered trays, boxes, and toys that are made in some Indian villages. The brightly coloured Japanese trays are different, and have nothing to do with lac. But what in the world is lac?

Lac is produced by a small insect, *Carteria lacca*, allied to the one that makes cochineal. It is a native of India and lives on various kinds of trees, such as the khusum, the dakh, and some species of *Ficus*. The young larvae that come out of the eggs creep about on the twigs in search of a juicy part. Into this they plunge their piercing and suctorial proboscis, and proceed to suck up sap. The females, which are greatly in the majority, are circular in shape; the males are smaller and ovoid. Both sink into a rather lethargic state of repletion, remaining fixed for eight to ten weeks, and secreting a sticky exudation which consists of resin mixed with a little wax. This is 'lac.' The female loses her legs and her feelers, and becomes filled with a brilliantly red nutritive substance which is called 'lake.' It is really a store for the future offspring.

The male's story is quite different. He loses his mouth-parts and can no longer feed, but he keeps his legs and grows a pair of wings. When he is quite mature he backs out through a slit on the under-surface of his shell or envelope of lac, sometimes badly called a cocoon, and crawls over the twig, fertilizing the imprisoned females. Then, more consequently than inconsequently, he dies.

To the female, however, fertilization is the beginning of a new chapter. She grows larger and secretes more and more lac. No doubt she would be smothered by her own physiological industry if it were not that she lengthens out a number of white respiratory filaments which project beyond the lac and are able to capture oxygen. This is an extraordinary contrivance, but something remotely analogous may be seen in Britain and other countries in a pool near a dungheap where the rat-tail larvae of the drone-fly (*Eristalis tenax*) have hatched out, and have lengthened out their rat-tail-like posterior filament to reach to the surface of the putrid fluid and capture the indispensable fresh air. Returning to the lac insect, we may note that careful observers tell us that the white respiratory filaments give the whole

tree a downy appearance. Animate Nature is a fathomless well of surprises.

The story of the female prisoner continues. She lays many eggs beneath her body and surrounds each with an envelope of wax. Then, having done her duty, she dies—a martyr to sex, and a monument to maternity. Perhaps she deserves a monument as being the most sedentary animal in existence, for even a sponge has a larval frolic in the sea, and the barnacle enjoys a free-swimming adventure before it settles down. Many of the reef-building coral-polyps have a short freedom in the waves; others, of course, arise by budding and fission. But the female lac insect never moves after her larval crawl of a few feet. What a life!

Her offspring emerge from the eggs, and are said to eat their way out through the body of their dead mother. They scatter along the branch seeking for a promising place, but they cannot creep for more than three or four feet or survive for more than three or four hours. Many are destroyed by wind and rain and by birds.

By this time, however, man has appeared on the stage. He cuts off twigs before the young ones, the larvae, have swarmed, and ties them on to the branches of other trees, so that these may be infected, and thus increase the supply of lac. Other twigs are left till the larvae have swarmed, and are then gathered and pressed between rollers to separate the lac from the wood. After complicated processes of melting and purifying, the shell-lac—the **shellac**—is spread out in thin sheets and sent to market. The water in which the lac is washed becomes bright red; it is allowed to stand till a sediment is formed; the clear liquid is poured off and the rest evaporated; the sediment is pressed into cakes of **crimson lake.** This used to be very precious in dyeing and also for water-colourists, but the European dyer at least has given his preference to the cheaper synthetic product, which does not interest the student of Natural History. In India, however, 'lake' is still used a good deal for dyeing and also as a cosmetic. Before lake gave place to aniline it was largely superseded by **cochineal**, a similar product stored in the body of another *Coccus* insect that feeds on cactuses. It is a native of Mexico, but was successfully introduced into the Canary Islands and at several places on the shore of the Mediterranean. But cochineal has also retreated before the advance of chemistry.

While 'lake' has largely disappeared, there is still a large export of 'lac,' especially to Great Britain and the United States. It is one of the ingredients of sealing-wax and lithographic ink. Mingled with other resinous substances it is used for stiffening 'silk' hats. Dissolved in alcohol and coloured with a transparent yellow, it is used for lacquering brass. Of recent years the spirit varnish has found an

extensive use in some electrical processes, and in the manufacture of gramophone records. Some of these linkages are very quaint; it would make a series of good Natural History conundrums to ask the connection between rainstorms in India and silk hats in Piccadilly; or between Indian ants, which often browse on the lac and eat off the indispensable respiratory filaments, and the gramophone records of the latest popular songs; or between coccids on the dakh tree and gas-brackets in the drawing-room.

If one rests on a holiday beside an old wall half covered with moss, it is of interest to pull off, not too wantonly, some of the tufts to discover the hidden or cryptozoic life sheltered beneath. In some cases one has the good luck to find a sluggish snow-white insect with pink legs and feelers. The female of this *Orthezia* is often the size of a split pea, and is a relative of the lac insect. When one scrutinizes her, one sees that the snow-white covering is not the insect herself, but an exudation exactly comparable to lac. It sometimes forms a trailer behind the body, and under the shelter of this the eggs and larvae may be found. Orthezia is worth looking for. There is no doubt that these Coccus insects have a *penchant* for making strange products, for manna and honey dew, white wax and the medicinal axin, ground pearls and cochineal are all to their credit—besides lac and lake.

Alligator Farms

Sometimes, no doubt, man is ingenious and even daring in his exploitation adventures, and it is still quaint to read of 'alligator farms.' It seems that there is one such farm in Florida with six thousand 'head' of alligator. They are captured in the rivers and marshes and fed in fenced ponds on fish and low-class meat. A big alligator is said to require over thirty pounds of flesh for a meal, but, fortunately, they fast during the five winter months. They do not suffer from any diseases; and, if they lose a tooth, there is always another one ready to take its place. Unlike most animals, they have no limit of growth, and their longevity, though not accurately known, is probably prodigious. Certain American authorities have estimated it at ten centuries, though perhaps this is somewhat optimistic. There is no doubt, however, that a male alligator twelve feet long shows no sign of senescence. The economic significance of the alligator farms is that the hide is in demand for bags and wallets, one of average size fetching fifteen to twenty dollars. An average alligator also yields about a gallon of valuable oil. For living specimens there is a considerable trade with zoos and menageries. The female lays forty to sixty large eggs about midsummer, scooping out a hole in the mud. The young hatch out in a couple of months and are self-supporting from birth.

Medicinal Uses of Animals

The medicinal leech (*Hirudo*) must be given first place for historical reasons, but it has gone sadly out of fashion in modern times. Blood-letting is no longer regarded as a cure for all the ills of our flesh; leech-gathering is no longer a lucrative occupation for the pensive. 'Send for the leech,' they said in the sixteenth century, when we should say, 'Send for the doctor'; but it is not for us to discuss how exactly the animal's name became transferred to the physician who used it (see the *Oxford English Dictionary*).

The medicinal leech feeds normally on the blood of fish and frog, a good meal lasting it for months.

In the mouth there are three semicircular jaw-plates, about the size of half a pin's head, and each bears along its margin sixty to ninety microscopically minute teeth, well worth looking at. Each jaw-plate might be compared to a circular saw, but its shape is more like a crescent and the teeth are minute cones.

After the jaw-plates are pressed against the victim's skin they are moved repeatedly inwards and outwards, and make three linear cuts. As the inward-outward sawing continues, the wound becomes more like a clover leaf. As the cuts broaden they coalesce, and the wound acquires a triangular shape, which allows of a continued flow of blood. Minute glands opening into the mouth secrete a ferment (*hirudin*) that prevents the blood from clotting. This anti-coagulant may help the flow of blood from the wound, but its main use is probably to keep the blood unclotted in the eleven pockets of the crop where it is stored before passing into the short digestive region.

It may be noticed that while the horse-leeches would work well for blood-letting as far as appetite goes, their teeth are not suitable for medicinal purposes.

One of the more modern items of fact in regard to the leech is that it has in its nerve-ganglia certain cells corresponding to the 'chromaffine' cells in the Vertebrate suprarenal bodies that secrete the powerful hormone called adrenalin. This is very interesting because the core or medulla of the suprarenal body is developed from the sympathetic nervous system, so that the state of affairs in the leech may represent an ancestral condition. It is possible that Vertebrates evolved from ringed worms or Annelids. In the second place, these 'chromaffine' cells have been found only in three or four backboneless animals—the leech, the earthworm, the so-called sea-mouse or *Aphrodite*, and another marine worm called *Eunice*.

What other medicinal animals are there? A place must be still allowed for the so-called Spanish fly (*Cantharis*), one of the numerous blister-beetles. The body produces an irritant substance, often called

cantharidin, an extract of which is used in making 'fly-blisters.' They are not so fashionable as they used to be, but they have not ceased to hold their own. They set up a superficial irritation and blistering which may relieve rheumatism, stiff neck, and the like. But the reckless internal use of tincture of cantharidin for a variety of inflammatory conditions is a thing of the past. It is not clear what the blistering substance means in the internal economy of the insect that produces it, but it occurs in numerous species. There is, indeed, a book of 550 pages devoted entirely to blister-beetles.

In some oil-beetles there is an exudation of drops of a yellowish, acrid, oily fluid from the joints of the legs, and this is probably offensive enough to be protective against certain enemies.

Speaking of blisters, we should not like to make much fun over the old practice of allowing a rheumatic arm to be thoroughly well stung by hive-bees, for the injection of the poison (which includes formic acid) has remarkable effects on some constitutions. In old days it was believed that a prolonged course of stinging, continued for about a month, rendered the valiant patient not only indifferent to bees, but immune from rheumatism. Such heroic treatment certainly deserved reward.

If one were to include all the antiquated 'animal simples,' the list of medicinal animals could easily be made enormous. But the great majority of these antiques are entirely superstitious. The dust of a dried magpie was prescribed for epilepsy and a diet of lizard was supposed to cure leprosy. There are, as every one knows, scores of these absurdities, which are not even interesting or amusing.

For others, however, some scientific justification may perhaps be found if one is generous. Thus, dried toad might contain the poison *phrynin*, which is known to have a rapid effect on the blood-pressure; and eating the raw liver of a fox is not without its suggestion of modern medicine. There may have been in some of the ancient prescriptions vague adumbrations of the modern treatment of patients suffering from thyroid deficiency, with the thyroid gland of sheep or calf administered in some form or other. But a revision of the old 'animal simples' seems to us, on the whole, very disappointing. Most of them spell foolishness.

On the other hand, it seems fair to include among medicinal animals certain venomous snakes whose bite is an antidote to their own poison. This is true, for instance, of the adder. It might be stretching a point to drag in those snakes whose poison is counteracted nowadays by an antitoxin serum prepared from an appropriate animal that has been bitten or injected.

More defensible would be the inclusion of sundry fishes from which very pure insulin can be extracted. And if cod-liver oil is a medicine,

codfish ought to have an honourable position on our list as the producer of one of the most valuable of vitamins. But even when we cast our net as widely as possible, we cannot help contrasting the small number of genuine medicinal animals with the large number of genuine medicinal plants. Is not the moral that there should be a fresh search through the animal kingdom? We might discover the elixir of life in our scrutiny.

Utilization of the Spoils of the Sea

The Aquarium at Monaco, to which we have already referred (see Index), has an extraordinary luminosity, both physical and intellectual, and a carefully thought-out aesthetic quality. Even the gorgeous chandeliers are phosphorescent jellyfishes, the curtains are fine-meshed tow-nets, the pavement on which you tread is decorated with the lovely jetsam of the sea. Another conspicuous feature is the way in which the visitor is shown how everything has been found out. A laboratory, taken from one of the late prince's exploring yachts, has been rebuilt in one of the spacious halls; and another room is given to all the dredges and trawls, sounding apparatus and sample-capturers, self-registering thermometers and pressure-gauges, besides devices for taking submarine photographs in very dim light. And through it all there pours the generous Riviera sunshine, skilfully moderated so that the specimens are not bleached. The great hall, where lectures are given and learned congresses meet, is a blaze of tempered light, and yet it can be darkened in a minute to show a lantern slide.

Under the skilful directorship of Dr. Jules Richard, one of the halls of the museum has been devoted to a display of the treasures that the sea has placed in man's hands for his utilization. Every one knows, of course, that there are all sorts of beautiful and useful things to be got out of the sea; but it is very impressive to find them set forth in a spacious hall regardless of expense. Let us walk round.

We begin with beautiful specimens of the diverse kinds of bath sponge, which have done something as factors in civilization. Then come corals—red, blue, and black—some of them worthy of a queen. Not very familiar are necklaces fashioned from the rough root-knobs of the precious coral, ornaments full of character. Very fascinating lamp-shades are made of cleaned and clarified sea-urchin tests, and the not distantly related sea-cucumbers are dried into sausage-like *bêche-de-mer*, a common Oriental comestible. In the fish-markets of Mediterranean ports one sees more than one kind of sea-urchin exposed for sale, the ovaries forming the edible part. The museum includes samples of the palolo-worm, which once a year makes several

coral seas like vermicelli soup and affords abundant feasting for crabs and natives alike. The heads of the greenish or yellowish worms remain in the crevices of the reefs, and set free the bodies laden with germ-cells, which are liberated in the waves. What a quaint evasion of reproductive death, for the heads grow new bodies for another season!

Crustaceans are illustrated by many kinds of toothsome shrimps and prawns, and by the minute plankton from the surface of the sea—atomies on which shipwrecked mariners in an open boat might feed for many a day if they had any way of catching them. Few of us have realized vividly enough what scores of things can be made of shells—cups and spoons, lamps and ladles, buttons and window-panes, cameos and coins. How curious these amber-coloured silken tassels made of the byssus threads with which the noble pinna, like our common mussel, anchors itself to the substratum! What variety, from a pearl to a font for holy water!

We did not know before that more than one sea-squirt is used as a titbit on the Mediterranean. The tunic of cellulose is peeled off and the enclosed animal is swallowed like an oyster. *Microcosmus* is one of those edible curiosities, known as *vioulets* at Marseilles. Higher in the scale are the fishes, whose uses are manifold, though far from being exhausted. The shelves show caviare, oil, gelatine, glue, and many an edible fish from sardine to tunny.

Wonderfully attractive are the utilizations of tortoiseshell, for combs and card-cases, for the boards of books and the mounting of spectacle lenses. But sea-reptiles cut a poor figure beside sea-birds—with their quilts of down, their oil for lamps, their plumage for decoration, their eggs for food, their guano to transmute into bread! From the great albatross down to the tiny Mother Carey's chicken, what a gamut of sea-birds!

Sea-mammals are represented by seals and sea-cows and cetaceans, large and small. Whale-oil and spermaceti, whalebone and porpoise laces, treasures of beauty cut out of cachalots' teeth—all are there, and more also.

We must not forget the plants of the sea: the seaweed that once again is being made to yield iodine, and the agar-agar on which the bacteriologist grows his cultures; the sea-grass (one of the few marine flowering-plants) that is wound round the bottles of olive-oil and chianti; kelp for burning; and carragheen for invalids—all are there.

Hundreds of specimens, all from the sea and all of use to man! Some are familiar, and others are rare; but the cumulative effect is very impressive. One cannot help thinking that if all these uses have come to be known without much searching, what an abundance of riches there must remain to reward those who would systematically

search the creatures of the sea from the vantage-ground of the zoologist and the biochemist. There must be a treasure-house in the sea's abundant progeny.

Another very interesting feature of this unsurpassed collection of usable marine creatures is its illustration of the artistic suggestiveness of many. The modern culmination of this is in the beautiful glass-work of Lalique; but it is an historical lesson to look at the fumbling anticipations of this by ancient—sometimes prehistoric—artists. Zoöphytes and seaweeds, corals and shells, and scores of other things have been actually used in making decorations—sometimes more quaint than beautiful; but much more important, we think, is the way in which marine creatures have inspired artists in some material and manipulation of their own.

Animals that Bite Man's Heel

We all feel some pride in the victories of medical science over disease. Of many places it may be said that malaria has shrunk before the simple expedient of pouring a little petrol on the pools where the young mosquitoes develop. For this makes a slippery surface film on which they cannot hang their breathing-trumpets, and they drown. But without mosquitoes, to carry them from patient to possible patient, the **malaria organisms** cannot continue. Thus for some years there was a complete disappearance of malaria from Khartoum, where it used to be rife, and the same might be said of many other places. In this connection it is always worth remembering that the dapple-wing mosquito (*Anopheles maculipennis*), that carries the malaria organism in a country like Italy, is common in some parts of Britain, yet is no longer worse than troublesome, since the malaria or ague organism called *Plasmodium*—a microscopic animal—has disappeared from these parts.

Perhaps the heaviest mundane cloud that has ever rested on the human race in warm countries is **ankylostomiasis**—an awful name for a dire disease. It is due to a contemptible little threadworm, represented by several different kinds, that enters man's body, as a microscopic larva, through cracks in the skin, and establishes itself in the food-canal, where it sucks blood from the walls. This results in serious anaemia and weakness, often ending fatally. Travellers, missionaries, and employers have spoken of the dreadful 'tropical depression' that is produced among the natives by these 'hookworms'—a loss not only of strength but of the will to live. Zoologists have cleared up the life-history of this parasite, which spends its larval life in contaminated soil, and medical men have shown how it may be readily expelled from the body, e.g. by doses of carbon-

tetrachloride, and how infection may be prevented by theoretically simple sanitary precautions, and by avoiding places where the soil has been fouled. The worm usually enters the natives through some abrasion on their bare feet. But our present point is that through energetic anti-hookworm campaigns, maintained especially by the Rockefeller Institution, the percentage of infection has been reduced in some places from twenty-five to two. There is no reason, save slackness, why this heavy hookworm cloud should not disappear altogether. This is a diagrammatic instance of a gratuitous handicap, for, as Maarten Maartens wisely said, 'many evils are of man's approving, not of God's appointing.'

They say that every third child in Cairo (30,000 born every year) suffers from the painful disease of bilharziasis, and in some places every third adult is infected. Again we have to do with a small parasitic worm, represented by several different kinds (*Bilharzia* or *Schistosomum*), which enters the human skin, occasionally the lining of the mouth, by cracks or abrasions. It establishes itself in the blood-vessels of the bowel or of the bladder region, and the microscopically minute eggs have a spine which cuts into the delicate walls when the unfortunate host moves about. Thus it is a painful disease and involves much loss of blood. It has often been a source of great trouble to our soldiers in Egypt and elsewhere. Now, Bilharzia belongs to the class of flukes, though it does not look like one; and it has a life-history in many ways like that of the common *Distomum* (q.v.), the cause of liver-rot in sheep. As Major Leiper, a Glasgow graduate, discovered during the war, the larval stages occur in certain freshwater snails, and the microscopic final larva, like a transparent forked thread, swims for a short time in the water, and enters man's skin through some crack or 'chap.' Originally, no doubt, there must have been some other host, but nowadays man is the victim that we know about; and we can understand at once why bilharziasis should be common among washerwomen, among gardeners who water the flowers, among children who paddle about, and among soldiers who bathe heedlessly. The elimination of the water-snails is hardly practicable, but Major Leiper showed that the microscopic larvae cease to be infective and die off when the water in which they are living is drawn and kept quite still for thirty-six hours. Water used for drinking purposes can of course be filtered thoroughly, but Major Leiper's simple suggestion applies to cases where filtering is not practicable. We have given some details in regard to these three cases because they illustrate what may be called the distinctively modern method of focusing scientific light on the practical problem of balking heel-biting serpents.

In contrast to the older fatalism, expressed, for instance, in Luther's

strange saying, 'This world 's a bad business, may God soon put an end to it,' there is scientific meliorism—a robuster faith. Face the facts, get to understand them, and control will follow. Pasteur was to Darwin as works to faith, and there is a notable linkage of achievements connecting Pasteur, a great initiator, with his latest continuators in the field of pathological research.

No doubt the idea of conquering disease by understanding it is as old as Hippocrates, but the careful focusing of different rays of scientific light on a problem is modern. In regard to the imaginative founding of 'Salomon's house,' which was a kind of institute for experimental evolution, Bacon said with his familiar grandiose reach: 'The end of our foundation is the knowledge of causes and the secret motions of things, to the expanding of the bounds of human empire and the effecting of all things possible.' And one remembers another of his great sayings, that science is 'a rich storehouse for the glory of the Creator and the relief of man's estates.'

We have referred to three little serpents that continue to bite the heel of evolving man—the malaria organism with the mosquito as its vehicle, the hookworm that needs no carrier, and the bilharzia fluke that links water-snail to man; and it will be noted that one aspect of human evolution is that his 'wild beasts' become smaller and smaller. Plasmodium is, of course, invisible except through the high power of the microscope, but it is vastly more important than a huge python. Hookworm and Bilharzia are both small, but they are more formidable than all the beasts of prey. The other outstanding fact is that man is now crushing these heel-biting little serpents underfoot, and almost always in the same way — by discovering the secret motions of things. To the three instances we have given it is easy enough to add others, but the logic and the moral would be the same. It matters little whether the 'serpent' is of the animal persuasion, like the *Trypanosoma* of sleeping sickness, or a virulent plant, like the bacillus of bubonic plague, especially since the vehicle in this last case is again an animal, to wit, the rat-flea. The subtlest cases are those where the disintegrative intruder is beyond the limit of size that the ordinary microscope can detect, or the best of filters can exclude. Yet here also there is hope, as recent cancer research shows. It is difficult, of course, to be patient with the lugubrious darkness that still besets many important problems, such as 'foot-and-mouth disease' in cattle, but we fight under a standard that has never seen defeat—even in retreat!

DEATH-DEALING INSECTS.—In fine summers there are often plagues of insects. This is indeed the fly in the ointment—mosquitoes in some places, wasps in others, midges everywhere. Sometimes the trouble is due to the contemptible little insect, the mosquito-like

Theobaldia annulatus. It punctures us with great quietness and quickness, introducing bacteria that raise painful and unsightly swellings. It is a black mosquito in the wide sense, distantly related to the dapple-wing.

Of recent years the true dapple-wing mosquito, *Anopheles maculipennis*, has become seriously common in many parts of Britain; and though it is not yet carrying the malaria organism, it may begin to do so while most of us are still only entomologizing at the best, or complacently ignorant at the worst. It is not a pleasant historical fact that in bygone days the harvest was sometimes lost in various parts of Britain, even as far north as Inverness, because of the prevalence of 'ague' (or malaria) among the labourers. Forewarned should be forearmed; and why should not the indefatigable boy scouts learn to hunt down dapple-wings? It would make for precision of observation as well as for agility; and it would be social service.

But one of the many reasons for congratulating ourselves on living in a north temperate country is that plagues of flies are, after all, much moderated by the sterner climate. We make a burden of our little grasshopper, if we may venture on an allusion to what is probably a Biblical mistranslation, but the sum total of all the insect pests that directly attack man in a country like Britain is a very small affair compared with the tsetse flies of Africa. For the tsetse flies (*Glossina*) are the carriers of the deadly organism (*Trypanosoma*) which causes various forms of sleeping sickness in man. There are eight different kinds that carry disease-producing species of trypanosomes which affect either man or domestic stock in Africa.

Nowadays, at any rate, the species of *Glossina* are confined to Africa, with the exception of one that has extended its range into the Arabian hinterland, but the conjecture has been hazarded that the puzzling long-ago disappearance of horses from the American continent may have been due to tsetse flies. In any case, the tsetse is a pest of long standing, older than the plagues of Egypt, since fossil specimens of Glossina are known from Pleistocene deposits. For a creature of its size, like a blue-bottle, it has made a big mark in the world!

Professor R. Newstead, of the Liverpool School of Tropical Medicine, has recently published an authoritative and finely illustrated guide to the study of the tsetse flies, which he has been studying for twenty years, and he gives a clear account of what may be regarded as established amid much that is still uncertain. The cause of sleeping sickness in man and of allied diseases in domestic animals, such as horses and cattle, is infection with *Trypanosoma*, a microscopic animal, not a bacterium, which runs riot in the blood and various organs of the

body. It is more like a microscopic beast of prey than a parasite, and its invasion is very apt to be fatal. Man is infected by being bitten or punctured by the tsetse fly, which is itself tolerant to the presence of the deadly organism which it carries. If a tsetse fly is interrupted in making a meal of infected blood, say from a man with sleeping sickness, it may settle on another victim and mechanically transfer some trypanosomes on its proboscis from the first host to the second.

But the trypanosome that causes such serious diseases in man and his stock is only incidentally, as it were, in these hosts. The belief of most investigators is that the natural reservoirs, so to speak, of trypanosomes are certain (or rather uncertain) wild animals, which are immune to the presence of the organisms that carry death elsewhere. It is a familiar fact in regard to many parasites that they establish a give-and-take relation — a *modus vivendi* — with their *original* hosts, but run amuck inside a new host into which they have been more or less accidentally introduced.

The explanation is that the new host has no counteractives or 'anti-bodies' ready to parry or blunt the thrusts of the intruder. Thus measles, which is not usually a serious disease in Britain, may run riot if introduced among the natives of a distant island. Similarly, it is believed that certain kinds of *Trypanosoma* which are very virulent in man and his stock are harmless to the 'big game' in which they are, so to speak, at home. But it is uncertain what wild animals *are* the important 'natural reservoirs.' Indeed, no fewer than seventeen different kinds, including several antelopes, have been incriminated.

A very interesting point is that immunity to trypanosomes occasionally crops up in domestic animals and in man. This suggests the possibility that if evolution goes on long enough more immune races might arise. But as we cannot wait for that, endeavours are being made to discover drugs which will act against sleeping sickness as quinine does against malaria, or injections that will be life-saving, or ways of reducing the number of tsetse's breeding-places in the vicinity of man's settlements, or ways of keeping the 'natural reservoirs' at a distance. There is a danger, however, lest the retreat or elimination of wild game may deprive tsetse flies of their natural food, and thus lead to an intensification of their attacks on man. What an intricate bioplex it is!

POISONOUS FISHES.—Sometimes on a visit to an aquarium one gets a chance of admiring the sinuous grace and subtle coloration of a *Muraena*, sometimes over a yard in length, which twines itself in and out amongst the rock-work. It is a kind of eel, not uncommon in the Mediterranean, and extending to the west into the Atlantic, and to

the east into the Indian Ocean. There is something sinister in its snake-like body and in the apparent causelessness of its tortuous movements, and it is reputed to be the only fish that gives a poisonous *bite*. There is no doubt that fishermen may suffer severely from the wound made by a vicious snap of a captured Muraena, but this may be due merely to the introduction of the slime of the mouth, almost certainly laden with bacteria. For recent examinations of the tissue at the base of the palate teeth by Coutière and by Pawlovsky contradict previous reports of a special poison-gland. There seems to be nothing peculiar in the Muraena's mouth, only the usual abundance of unicellular glands secreting mucus, as in almost all other fishes. For practical purposes, however, the Muraena gives a poisonous bite, though there may not be any special venom-gland comparable to that of poisonous snakes. The flesh must be safe enough as food, for the Romans, who thought a great deal about their meals, ranked the Muraena above all other fishes, and reared it on unmentionable diet in special ponds by the sea.

From ancient times it has been well known that certain fishes could give a poisonous wound by means of special spines or sharp fin-rays. In some cases, like the weever and bullhead, there are special multicellular **poison-glands** at the base of these sharp spines; in other cases, like the sting-ray, the skin covering the base of the spines is very abundantly provided with the ordinary unicellular glands characteristic of the epidermis or outer skin of fishes. But the poisoning that follows from the entrance of albumin and mucus from the skin-glands may be almost as severe as that brought about by the specialized secretion of a well-developed poison-gland.

One of the most formidable of the poisonous fishes, although with no special poison-gland, is the already mentioned sting-ray or *Trygon*, (q.v.) a near relative of the skate. It may be three to six feet in total length, and its attenuated tail bears towards the end a long serrated spine, partly covered with glandular skin. As the fish lashes about with its tail it may give an ugly wound, and it is possible that bacteria may enter along with the skin-secretion. A fisherman may also get a bad wound by inadvertently stepping on the tail-spine when wading in shallow water, for the sting-ray sometimes lies near shore, with the bulk of its body buried in the sand. The wound is extremely painful, and the limb becomes swollen and temporarily paralysed. Fatal cases have been repeatedly recorded. We read of the death of one of the Greek heroes that it was due to a wound from a fish's tooth, the reference being in all probability to the use of the sharp Trygon spine as the head of an arrow or spear.

The bony fishes called 'weevers' (*Trachinus*) are much smaller than the gristly sting-rays, but they are much more troublesome.

On the gill-cover there is a backward-projecting spine, with a groove along each side, and in the skin, which covers all but the sharp tip, there are two pear-shaped poison-glands. When the weever protrudes its gill-cover and jerks its body, the spine may enter the skin of an assailant, whether animal or man. The pressure on the glands when the wound is made seems to burst them, for there are no detectable ducts; and then the poison is exuded into the grooves of the spine. There are smaller poison-glands at the base of five or six sharp fin-rays in the anterior dorsal fin, and they work in the same way. Fishermen are wounded in handling the weevers or when wading in the water, and the effect is often alarming. Burning pain may be followed by difficulty in breathing, by disturbances of heart and pulse, even by delirium and convulsions. In some cases the poisoning has ended fatally. The wound is but a small puncture to start with, but the inflammation spreads, and a cure is sometimes very difficult. A fisherman has been known to be disabled for two months. The specific names of the two British weevers, *Trachinus vipera* and *Trachinus draco*, express the widespread feeling that these fishes are not creatures to be played with.

The name 'sea-scorpion' is sometimes given to the marine bullhead, *Cottus scorpio*, one of our common shore fishes; and the reference is to a paired poison-gland situated at the base of the third spine on the gill-cover. But the secretion does not seem to be venomous except during the reproductive period, from November to January, a fact that has been noticed in several of the poisonous fishes. The physiological significance of this fact is still obscure.

One of the toad-fishes called *Thalassophryne* is interesting in showing a more highly evolved **poison-apparatus.** In the Panama species the gill-cover bears a poison-gland and also a poison-reservoir, and the backward-projecting opercular spine is perforated by a canal, thus reminding one of the fang of a viper. The canal is open at the base of the spine and at the tip; and it is an evident advance on the grooves on the spine of a weever or the like. The first two rays of the dorsal fin are also hard and hollow, and there is a poison-gland at the base of each.

Many of the poisonous fishes that have been reported show the weever type of apparatus, that is to say, they have a multicellular poison-gland associated with the base of a specialized spine; but only a few have been studied in detail. Similarly, in regard to the poisonousness, its precise nature is known only in a few cases. There are almost as many theories of the weever's poison as there have been investigators, but the general effects of the wound include a paralysis of nerves, a slowing down of the heart-beat and of the breathing movements, a dissolution of blood corpuscles, and local inflammation

around the puncture. As well-known experts contradict one another flatly, it seems worth asking whether the nature of the poison may not vary with the time of year and with the constitution of the fish. Of course great care has to be taken to get the poisonous secretion in a pure and sterilized state, and no one would draw any biochemical conclusions from the consequences of a dirty wound.

Most of the fishes that have been reported as poisonous are marine, but there are a few exceptions to this rule. Thus the 'mad toms' of some North American streams have poison-glands associated with the dorsal and pectoral fins, and give a prick which is said to resemble the sting of a bee. Perhaps it should be noted that thorough cooking destroys the poisonousness of a poison-gland, and in any case a poisonous fish has quite harmless flesh. The weevers and the sea-scorpions are often eaten. Indeed the flesh of poisonous fishes is in most cases peculiarly wholesome, and often palatable as well. Incautious consumption of imperfectly preserved fish, e.g. sturgeon, or of 'high' fish, e.g. mackerel, may be followed by nervous poisoning, gastric disorders, a rash on the skin, and so on. This is a difficult subject, but we may note that these serious consequences are sometimes due to the fact that the proteins of the fish have broken down into toxic products (**ptomaines**), while in other cases they are due to the presence of a particular bacillus (*Bacillus ichthyismi*) which produces poisons in man's food-canal. But in more than ninety-nine cases out of a hundred we can enjoy our fish with an easy mind, especially if it is not an oyster!

Man's Mistakes

Partly through ignorance, partly through carelessness, and partly through a common willingness to acquiesce in 'muddling through,' man has made many mistakes in his practical relations with the animal world; and many of these mistakes have cost him dear. We shall give a few illustrations.

(1) Man has often been very short-sighted in introducing plants and animals to a new country, where they have run riot and done much mischief. Sometimes, as in the case of ship-rats and many weeds what man must be blamed for is not deliberate introduction, but acquiescing in introduction. Frequently, however, he has had no excuse; thus he deliberately introduced rabbits into Australia and European sparrows into the United States. His recent introduction of the American musk-rat into Europe has proved a menace, but it is hoped that strict control will obviate disaster. The fostering of the grey squirrel in Britain seems to most naturalists very foolhardy, for it is quickly multiplying and spreading, it does much harm in

orchards and woods and among young birds, and it is, in some way not very clear, driving away the native red squirrel which levies a lighter tax.

(2) The opposite kind of mistake is allowing certain forms of life to become scarce, and so disturbing the **Balance of Nature.** Thus a too severe shooting down and trapping of birds of prey and carnivorous mammals tends to remove the useful natural checks on the multiplication of small rodents, like voles and mice, which do much damage in the farmer's fields. An improvident or an enforced deforestation may have far-reaching consequences which are against man's interests; thus it may mean that certain useful birds disappear from the region where they can no longer find shelter. Sometimes, no doubt, the price has to be paid, as in the case of swamps which have to be drained. The disappearance of certain useful and interesting marsh birds, like the bittern, is in part a result of the reclamation of the land in the name of agriculture.

(3) Since man began to colonize Scotland, perhaps 10,000 years ago, there has been a disappearance of various interesting mammals, such as reindeer, bear, and wolf, and of various interesting birds, such as sea-eagle, osprey, and great auk. Others, again, have become very rare, such as raven and kite, pine-marten and badger. The disappearance and the rarity must be deplored on scientific and aesthetic grounds, but it is more or less certain that there has been economic loss as well. It should be noted, however, that the total list of the fauna has not been reduced, for aliens have taken the place of those that have been exterminated. Instead of the reindeer we have gained two rats; instead of the sea-eagle we have gained two cockroaches. The examples we have chosen are not unfair, for they illustrate the fact that while fresh introduction has balanced extermination as regards numbers, there has been a reduction in the quality. The standard of the fauna has been lowered. We do not, however, push this to the extreme of suggesting that we can return to the old days when wolves ran about plentifully in our holiday haunts in the Scottish Highlands.

(4) Man utilizes the variations with which Nature supplies him. As yet it cannot be said that he has more than begun to provoke the new departures, though the use of radiations is known in a few cases to be a provocative, and so also is change of surroundings and crossing. The large fact is that Nature supplies the novelties from the fountain of change in the germ-plasm, and man can sometimes make use of them, especially in domesticated animals and cultivated plants. He detects a novelty that pleases him, he isolates it, fosters it, multiplies it, interbreeds it with others like itself, and gradually builds up a new breed—the 'Marquis' wheat or the loganberry, the Pekinese dog

or the short-legged Ancon sheep. Where man may receive praise or blame, then, is not in the production of the new, but in its selection; and in this he seems to us to have made some mistakes—selecting for what is not worth while, such as some 'fancy' dogs and garden flowers, or selecting for what implies lack of vitality and balance. Thus he has selected a breed of pigeons so short in the bill that they cannot get out of the egg-shell without human assistance! On the whole, man has been successful with his domestications and cultivations, but he has sometimes made mistakes.

RATS

By far the most injurious animals in Britain are the rats, and in spite of the energetic measures taken to reduce their numbers they remain a very serious menace. They destroy enormous quantities of stored food, and spoil much more than they destroy; they do great damage to property by burrowing and gnawing; and they are vehicles of several formidable diseases. They multiply prodigiously, and there is probably one rat at least for each member of our population. They are continually being introduced afresh from foreign countries.

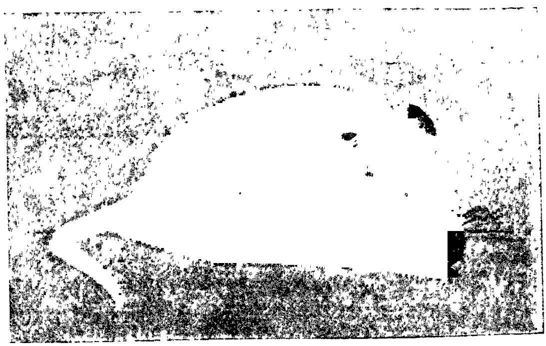


FIG. 463. THE BLACK RAT

THE BLACK RAT.—Neither of the rats now represented in Britain can be called a native. Both are aliens from the East, and the first to come was the black rat (*Rattus rattus*), whose arrival in this country dates from the time of the Crusades. In the Mediterranean region and in the East it is represented by varieties of a much lighter colour. Thus the Alexandrine variety, frequenting Asia Minor and North Africa, is brownish grey on the back, and the roof-rat of the Mediterranean region has the same part of its body yellowish or reddish brown. It seems that the black dress was acquired after the originally light-coloured *Rattus rattus* got a footing in colder countries, but it must be kept in mind that many of the 'black rats' (*Rattus rattus*) in Britain are actually brown, and many of the 'brown rats' (*Rattus norvegicus*) are black. This is a source of frequent confusion, and

shows that little importance can be attached to the colour until the species has been identified on other grounds, to be referred to later on. For many years the black rat was a serious pest in Britain, as in Europe generally, not only because of its destructiveness but because it harboured the microbe of the plague (or Black Death). In the early eighteenth century, however, its rival the brown rat was introduced, and within fifty years this new-comer had prevailed. About the middle of the nineteenth century the black rat was a great rarity in Great Britain. In several places, e.g. at Yarmouth, it has become common again, being introduced afresh by ships. Its climbing powers favour its prevalence as a ship-rat, and in this respect it is more successful than its cousin.

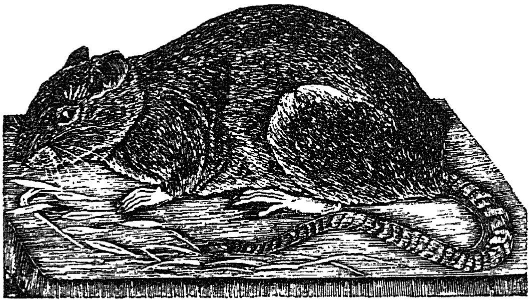


FIG. 464. THE BROWN RAT

THE BROWN RAT.—The original home of the brown rat (*Rattus norvegicus*) is in temperate Asia, and wild forms are still abundant in the region between the Caspian Sea and Tobolsk, and also to the west of Lake Baikal. It has become closely associated with man, and has been his shadow wherever he has sailed. It was not known in western Europe till 1716, nor in Britain before 1728. The colder the country the closer is the dependence of the brown rat on man.

Darwin referred to the internecine struggle for existence between the brown rat and the black rat, which resulted in the latter becoming almost extinct in Britain. But four points must be kept in mind: (1) the brown rat is the hardier species, more of an outdoor creature and not averse to the wetness of sewers; (2) it burrows better, and can gnaw away very hard material, and is therefore less balked than the black rat by barriers of stone and lime; (3) the brown rat is a much more indiscriminate eater; and (4) it is more plastic and tamable, as is well seen in the behaviour of its albino derivative the 'white rat.' No doubt the two species will fight when they must, but it is too simple to say that the brown rat directly killed off the black rat in the struggle for existence. As Dr. Chalmers Mitchell says: 'Each species has its different aptitudes, capacities, and preferences, and each insinuates itself into the most suitable environment. Possibly the extension of sewers and drains in this country has been a major cause of the greater success of the brown rat.' Moreover, we

cannot forget that the black rat is becoming common again in some places.

Black Rat (*Rattus rattus*)	**Brown Rat** (*Rattus norvegicus*)
Smaller, of slim build, with sharp muzzle.	*Larger, of heavier build, with blunt muzzle.*
Ears large, naked, almost translucent, reaching or covering eyes when pressed forwards.	*Ears small, hairy, thick, hardly reaching the eyes when pressed forwards.*
Tail slender, at least as long as head and body.	*Tail stout, never so long as head and body.*
Pads on soles of feet relatively large.	*Pads on the soles relatively small.*
Many slender grooved bristles in the soft fur. Usually ten teats.	*Grooved bristles fewer and more slender. Usually twelve teats.*
Adult weight rarely over 8 oz.	*Adult weight normally 14–17 oz.*

The two species are nearly related, but they differ through and through—even in the crystals that form when their blood is dried. There are marked differences in the skulls and teeth, but to appreciate these requires some apprenticeship. We must notice again that no reliance can be placed on differences in colour; and that differences in size and weight cannot be much utilized unless one knows that the contrasted animals are of the same age. A brown rat of 30 oz. is not uncommon, and one of 2 lb. 12 oz. has been recorded.

There should be no possibility of mixing up either of the rats with the water-vole (*Arvicola amphibius*)—badly called the 'water-rat—' for the water-vole is a heavily built animal, marked by a broad head, a blunt muzzle, inconspicuous ears, and a tail with a good deal of hair. It is not infrequently found exploring in fields at a distance from the water.

HABITS OF BROWN RATS.—Rats are most active in the darkness or semi-darkness. Their eyes can make much of dim light; and they have acute tactile sensitiveness in their whisker hairs (or **vibrissae**) and in their feet. They usually spend much of the day in their holes or burrows, resting and sleeping, and they often make comfortably lined nests. They often lay in stores of food. In their coming and going in the open they make runs, which are marked by their spindle-shaped droppings. Their inclination to keep to these wonted paths makes trapping easier, but every one knows of their suspicious wariness.

They are practically omnivorous, though vegetarian in wild conditions. The chisel-edged incisors are well adapted for gnawing, and part of the rat's activity in this direction, which sometimes seems gratuitous,

is necessary in order to keep the continuously growing incisor teeth from becoming too long. When the upper and lower teeth fail to meet properly, strange overgrowths occur which sometimes end fatally. Rats may attack hard wood, lead pipes, bricks, and cement; but what they gnaw in such cases is not swallowed.

The brown rat is not such a clever climber as its cousin, but still it can do wonders. It is a better burrower than the black rat and is much more inclined to take to the water. It swims and dives well, and follows watercourses in spreading from place to place. Although it often lives among filth, it is by inclination a cleanly animal, and makes a habit of bathing whenever it gets a chance. There is often a spring movement of rats from human habitations to the open country and a return to shelter in autumn. There is often a vigorous hunting of small animals in the open and a not inconsiderable destruction of eggs and young birds. The seasonal movement is to be distinguished from a trekking from one locality to another when overcrowding becomes intolerable, or when something occurs that makes flitting desirable. There are records of a unanimous departure from a haunt where the mortality from poisoning had been great.

Rats are sociable among themselves, though there is evidently an instinct which prompts them to kill and devour the maimed and weakly. Records of their 'courage' in attacking man are probably misunderstandings, for the circumstances usually point to the desperate boldness of starvation. Moreover, such abnormalities of appetite as attacking the feet of elephants are apt to seem stranger than they really are, for it is very improbable that it occurs to the rat that it is gnawing at the toes of a giant mammal. There is no doubt, however, as to the resourcefulness, ingenuity, and educability of rats. They form associations readily and they can learn in a short time to scamper through the passages of a Hampton Court maze.

Brown rats may be sexually mature when three and a half or four months old, and they can breed all round the year. The sexual season for a particular female extends for about nine months, and 'heat' occurs at intervals of about ten days. The male is always ready to pair. The female cannot be impregnated except at the period of 'heat,' which lasts for only a few hours. The period of gestation is about three weeks, and the female is ready to be impregnated within a few hours of the birth of a litter. The average number in a litter is eight, but there are often a dozen; and there may be five or six litters in a year. The female ceases to be fertile as she grows older—a fact sometimes overlooked in estimating the rate of multiplication. She is a careful mother, but in conditions of overcrowding, inadequate food-supplies, or captivity, she may devour her offspring. The young are born blind and naked, with their ear-trumpets sealed down.

Their eyes open in about a fortnight, and they are weaned in the course of their fourth week. It will be understood that many of the figures, such as the number of litters in a year and the number of offspring in a litter, vary greatly according to the conditions of life.

Two female rats kept in captivity are known to have had in thirteen months twenty-six litters, amounting altogether to 180 immediate offspring. But the young would begin to breed in three and a half to four months, so that the total numbers of descendants would be much greater. A common estimate is that a pair of rats, with six litters of eight in a year, would, with equal sexes and no deaths, be represented by 180 at the end of the first year. At this rate there would be many hundreds of millions from a single pair and their descendants in the course of five years. Of course this never occurs.

Writing in 1918, Mr. Hinton started from the assumption that there were 40,000,000 rats in Britain at the beginning of the year, that is about one per head of the population and about one per acre of cultivated ground. He supposed that 20,000,000 had a chance of breeding, and that 95 per cent of the breeding pairs died in the course of the year. He further supposed that 50 per cent of the progeny died at birth, and that only half of the survivors had a chance of breeding, and that the young effective rats were subject to a natural mortality of 95 per cent in the course of their first year. Even then, under suppositions so very unfavourable to the rats, the ten million pairs at the beginning of 1918 would be represented by 41,000,000 by 31st December. The cost of keeping them would be over £9,000,000, and the indirect loss entailed by their presence would be enormously greater. Mr. Hovell says that 'it would not be surprising if the damage sustained by Great Britain, say in 1923, approached one million pounds sterling per week.'

THE INDICTMENT OF RATS.—To the farmer's interests rats are in many ways seriously hostile. They devour large quantities of grain and other foodstuffs, and foul even more. They attack root crops and riddle stacks. They are hostile to pigs, poultry, and pigeons. They do much damage to property, even to the extent of undermining walls. It is said that in 1909 alone £2,000,000 was spent in providing rat-catching or rat-killing apparatus.

But the indictment is still more serious when we think of rats in connection with disease. The blood of the rat often contains the microbe of the plague (*Bacillus pestis*), and this is disseminated by the rat-flea when the plague-stricken rat dies and the flea happens to pass, not to another rat, as is usual, but to man. Even in these years of energetic action the bacillus of bubonic plague occurs among black rats in British seaports.

The dangerous *Trichina* worm, which causes trichinosis in man, is primarily at home in the rat. When a pig eats an infected rat it becomes trichinosed, and from the pig's flesh, if it is imperfectly cooked, the parasite reaches man. Mr. Hinton notes that in one instance the flesh of a single pig, escaping the watchful eye of the inspector, caused 337 cases of trichinosis, and of these 101 terminated fatally.

Another horror is that the dwarf tapeworm (*Hymenolepis nana*), which is very common in man, has the rat as its preliminary host. Rats are also said to disseminate a form of infectious jaundice. Rat-bite may cause a peculiar and serious fever.

Issuing from filthy places the rat may contaminate the food of man and beast with its germ-laden droppings, and there is reason to suspect that it is the vehicle of an intestinal disease (a kind of dysentery due to an amoeba) that troubles man. The circle of the rat's life cuts man's at many points, and always inimically, except that it affords a convenient animal for experimentation.

PRACTICAL MEASURES AGAINST RATS.—In many cases of animals that are hostile to man's interests, especially when they become numerous, we can find some counteractive in carnivorous mammals and birds of prey; and there is no doubt that weasels and stoats, kestrels and owls, and some other creatures levy a useful toll on rats. Everything should be done to encourage these natural checks. But the rat menace in Britain has long since passed beyond being averted by the Balance of Nature. Millions of these pests are living under the shield of artificial conditions which favour their survival and increase. Yet the serious danger is being energetically faced, and there is no doubt that man can get the better of the rat as soon as he devotes adequate energy to the problem.

The preventive measures include the protection of foodstuffs in rat-proof receptacles; the rat-proofing of houses, stables, stores, and stacks; the wiring of drains; the fumigation of ships and 'rat-shielding' of hawsers with large circular disks; the replacement of wood by cement, concrete, and brick in infested places; and, not least important, more careful disposal of refuse and reduction of the 'crumbs,' big and little, on which rats so largely feed.

The destructive methods are flooding, blocking, trapping, hunting, and ferreting, the use of poisoned food (e.g. with yellow phosphorus or barium carbonate), and fumigating the holes and burrows with poison gas (requiring careful handling).

In regard to prevention and cure we would make four general statements: (1) Success in putting an end to a dangerous and disgraceful state of affairs will be in proportion to the unanimity of action all over the country; (2) mere reduction in numbers will not give more than temporary relief, if a substantial breeding stock is allowed to

remain; (3) the extermination of mice should go along with the extermination of rats; and (4) no efforts are likely to be successful unless greater care is taken with the disposal of refuse and ' crumbs.'

THE SPREADING OF THE GREY SQUIRREL

It seems very short-sighted to allow this interesting and beautiful, but dangerous alien to increase in Britain as it is now doing. It seems to have been known for a century, but it did not become common till within recent years. Since 1889 there have been thirty-three introductions, and according to Mr. A. D. Middleton's recent study it is now widespread. At Burnham Beeches over 4,000 have been shot in the last ten years, and still they come. Our reason for alarm is simply that the squirrel is very destructive to trees, and that it is a sorry business to plant forests for these aliens to devour. The squirrel works definitely against tree-planting, which is in many ways so desirable, though to some extent its adverse influence may be counterbalanced by its habit of burying nuts and seeds, which it seldom troubles to dig up again. One species of squirrel is quite enough for a small country like ours, and to allow another one to get the upper hand seems to us to be extreme foolishness. As Professor James Ritchie says in his great book, *The Influence of Man on Animal Life in Scotland* (1920): ' The spread of the grey squirrel threatens us with a plague as grievous as that which rewarded the well-meant efforts of the enthusiasts who set the common red squirrel free in our woods, that his interesting presence might add to the delights of Nature lovers.' He quotes the verdict of Sir Frederick Treves that the grey squirrels ' eat everything that can be eaten, and destroy twenty times more than they eat.'

FIG. 465. RED SQUIRREL

The records of the past suggest, we think, that squirrels are more readily checked than some other rodents, such as rats, voles, and rabbits. For it seems certain that the destruction of forests in Scotland, terribly accelerated by the iron-smelters of the sixteenth, seventeenth, and eighteenth centuries, led to a practical, if not total, extermination of the red squirrel, so that it became by 1775 or earlier a great rarity, only known in the depths of remote forests like those of Rothiemurchus. But soon after its practical or total disappearance the red squirrel began to be reintroduced, and this reinstatement has been a success from the aesthetic and purely Natural History point of view, but a disaster economically. And now, slow to learn, we are introducing another species!

Very interesting to the biologist is the question of the relation between the new-comer and the native red squirrel, a question parallel to that between the black rat, our older alien, dating from the Crusades, and the brown rat, which did not reach Britain till about 1728 (p. 1376). But it is not easy to answer these questions, especially, perhaps, the question about the two squirrels. Some observers have seen combats between the two kinds, and have jumped to the conclusion that the new-comer is directly ousting the native species. But there is little evidence to warrant this generalization. In some cases the two species live amicably in the same wood; and since the century began there has been in some areas, still unoccupied by the grey squirrel, a marked decrease of the other. Mr. Middleton advises suspended judgment until more facts are gathered, but he seems disinclined to accept the popular view that the grey squirrel directly expels the red squirrel. He points out that our native species likes coniferous woods and feeds largely on seeds, bark, buds, and fungi, whereas the grey squirrel likes open mixed woods, spends much time on the ground (though active enough on the tree-tops, as many of us have seen in Scotland), and is almost omnivorous. Not only does it bark trees and eat off leading shoots, it devours bulbs and buds, fruit and vegetables, and like the red squirrel it is not averse to the eggs and nestlings of birds—especially of small birds who cannot defend themselves. Our conclusion is that one squirrel is enough. (See *The Grey Squirrel,* by A. D. Middleton. Sidgwick and Jackson, 1931.)

The Musquash or Musk-rat

In polite society, especially when there are delightful fur coats hovering round, it is usual to speak of musquash, not of musk-rat. And this convenience is justifiable on other than artistic grounds, for the musquash is not a rat except in a wide sense. It is much nearer the lemmings and the voles. Indeed its nearest relative in Britain is

the water-vole, whose (incorrect) alias is water-rat—a beautiful and interesting creature that does not receive the admiration it deserves.

The broad muzzle, the appressed ears, the small eyes, and the hairy tail proclaim the fact that it is not a rat; and no one could ever think it was who looked into its eyes. For the water-vole's expression is quite different from that of any rat; it seems to say: 'This is rather a hard world for gentlemen; the struggle for existence has driven me into the water; but I am getting on not so badly, thank you, and my wife is also well, thank you.' The water-vole is very clannish, but it is a convinced monogamist; and though there is just a hint of pathos in its eye, its expression is on the whole that of a likeable, quiet-loving creature who has conquered circumstances.

But let us return to the musquash, whose name is *Fiber zibethicus*. It is the largest of its tribe, with a length of about twenty inches from snout to tip of tail. The body is covered with soft brownish fur of admirable quality. But the tail of six to eight inches is hairless and scaly, and has the notable peculiarity of being flattened from side to side, so that it strikes the water like the blade of an oar. It is, in fact, an important steering and swimming organ; the feet are small and slightly webbed. The musquash is usually regarded as the best swimmer and diver among the rat-like animals.

On rivers with high banks the musk-rats make burrows, like our water-voles, but when there is a low margin they build dome-shaped houses of grass, reeds, and mud. These may be five feet in diameter and rise two to four feet above the water. Dr. Hornaday, of the New York Zoological Park, tells us that the houses are always entered from the water and so low down that the ice does not close the doors. Inside the house there is a living-room and bedroom whose floor is well above the water-level. If there is a flood the musk-rats have to trek, and they are sometimes very cross, and even aggressive, on such occasions. Usually, however, they regard man with indifference, though his close intrusion makes them dive into the water with a loud splash, just like the danger-signal of our water-vole.

Musquashes are normally vegetarian and subsist mainly on the roots and shoots of water plants, which are sometimes stored in the houses as provender for the winter. But they are by no means averse to an occasional mussel or crayfish or some other freshwater animal. They are also blamed for making adventurous excursions by night to adjacent poultry-yards.

Musquashes have a vast geographical range in North America, for they occur from the Atlantic to the Pacific, and from the Arctic Barren Grounds to the deltas of the Mississippi and the Colorado. This indicates a tough constitution, a safe amphibious mode of life, an abundance of vegetable food, and notable fecundity.

The twentieth-century development of musquashes is of much interest practically and theoretically. As the fur is very valuable and the flesh eatable, under the name of 'marsh rabbit,' it has paid to allow the musk-rats free play, and the natural 'fur farms' have grown enormously. Their profitableness suggested an introduction of musk-rats into other countries, and in 1905 four individuals were transported from Canada to a nobleman's estate in Bohemia. There they succeeded only too well, for as their numbers increased without check they began to break down the banks of streams and the dams of fish-ponds, to eat too many crayfishes and mussels, to devour young trout and the like at the spawning-grounds, and to raid adjacent fields and gardens and poultry-yards. About 1914 Bavaria and Saxony were invaded; in 1924 Silesia; and in 1928 the introduced musquash had become a serious pest. Although there was a sale of 60,000 to 80,000 skins in Berlin alone, the spate of life continued —another warning of the danger of disturbing the Balance of Nature. Our British rats are costly aliens; introduced rabbits have been calamitous in Australia; the European sparrow has done untold damage in the States; and there are other well-known instances. Yet we look on with only languid interest at the spreading of the American grey squirrel in Britain!

Yet neither our experiences with these alien introductions into Britain nor the statistics of the increase of the musquash in central Europe have availed to deter us from experimenting on our own account. And we are already beginning to see and to feel the consequences of our rashness in thus interfering with the Balance of Nature.

In the hope of creating a new industry, the importation of musk-rats was, in 1928, permitted to a few fur farmers, under licence, and with strict regulations as to keeping the animals in close captivity. There were in 1932 fourteen such licensed fur farms in Britain. But it is impossible to keep the musquash in an enclosure; it is a burrowing animal and may dig down many feet, and many individuals made their escape. Their fecundity is excessive, and already they have become a plague over the east and centre of Scotland, the Severn valley, where in many places the banks of the river and some of its tributaries are undermined, in Shropshire, and in many other districts. The Ministry of Agriculture has now taken the matter up, but it will require continual and costly watchfulness to keep these destructive little rodents within reasonable bounds. For their numbers are computed already to run into millions, and as long as a few pairs escape death the menace will still be with us.

To humanitarians the musquash is of interest because its fur can be used to a considerable extent to replace that of nobler animals. It is very fine fur and it can be produced in great abundance at little

cost. No one can pretend that musquashes look the least unhappy as long as they have plenty of room and food, or that they are mammals of very high degree. Wearing musquash does not mean that a rare mammal is being exterminated, or that painful practices are being encouraged. We read that more than ten million musquash skins were sold in 1914 in London alone, and yet there is no hint of a falling-off in the numbers. It must be remembered that these rodents have several litters in a season, with six or more young ones in each litter. We have a great admiration for musquash skins on people worthy of them, and our admiration is not diminished by the queer way in which the creatures often change their species after they are dead. For some become Hudson seal, and others river-mink, and others sable !

The name musquash refers to the pronounced musky odour, which is secreted by skin-glands along each side of the body just as in the water-vole and shrew. Perhaps the odour is repulsive to enemies.

Vanishing Treasures

Man is so often a negligent trustee of the treasures of animal life, that it was a relief to record the modern story of the reindeer (p. 1348). But it must not be forgotten that the introduction of domesticated reindeer from the Old World was in part at least forced upon man because of the previous short-sighted thinning of the wild caribou. Nor can we forget that the interesting musk-ox (*Ovibos moschatus*), a unique ancient type, once very abundant, and with no natural enemies save wolves, is fast becoming a great rarity. For many years it has been unknown in northern Alaska, and on the mainland of Canada it only survives in a few protected herds. It is a deplorable muddle that we are making of our trusteeship; and biologists are by no means free from blame. There is lurking in us a predatory urge to secure booty for our museum, if not, and then unpardonably, for ourselves. As an animal becomes rare, the commercial ‘ collectors ’ close round about it, and the scientific experts are sometimes not far off. Public opinion should insist on the licensing of both. This is one of those problems in reference to which it is important to take a world outlook. The extermination of a walrus or a musk-ox, a quagga or a sea-otter, is more than a national or continental loss, it is an impoverishment of the whole world; and we fail to see why every big museum should help to exterminate by insisting on having a full complement of the vanishing rarities.

Perhaps we may seem unnecessarily vehement, but take a few sentences from Sir James Barrett's *Save Australia* (1925). Speaking of the Australian birds and mammals, he says: ‘ Except in certain places where enlightened citizens have protected them, they are all

disappearing. It is difficult for any one to show a visitor in the State of Victoria the larger marsupials or the lyre-bird. It is quite impossible to find the smaller marsupials except in a few favoured places and with great trouble. It is, indeed, feared that some varieties have been exterminated.' We are not pleading for an impossible humanitarianism in reference to animals that have become (or, oftener, have been allowed or even encouraged to become) *pests*; but we have confidence in appealing to all who love life to lean their weight against the extermination of irreplaceable treasures.

We were glad to hear that the New York Zoological Society had decided to send the director of their Zoological Park on a visit to Europe to see if anything can be done to save the European bison from extinction. It suffered terribly from slaughtering—partly coerced by hard times, but partly ruthless—towards the end of the Great War and afterwards. The great Caucasus herd disappeared altogether, in part before machine-guns, and the Lithuanian herd dwindled towards disappearance. According to the last report of the International Society for the Preservation of the European Bison, there are only fifty-nine pure-blooded specimens left over the whole area, the largest herd being the Duke of Bedford's at Woburn Abbey. The Americans have been such successful custodians of the related American bison that they may be able to offer some useful advice to save the European species from utter destruction. It would be a tragic discredit to civilization to allow this fine tenant of the primeval forests to disappear from the world stage. But it is touch and go now. How slow man is to admit that he is only a trustee of the animal kingdom!

Man as Conqueror of Insects

We are such strange mixtures of inertia and initiative that it is often necessary to stress one aspect of a practical problem in order to excite endeavour. As Tennyson said: 'Reversion is ever dragging Evolution in the mud'; and therefore we must be always sounding the danger-signal. It is easier to drift than to swim, so we broadcast warnings. Thus it is often that the biologist on the farm has spoken of the cloud that is so apt to gather in man's sky when insects get the upper hand. These rapidly reproducing creatures are a menace to the whole world, and there can be no relaxation in man's efforts to conserve the natural balance that keeps them in check. In an interesting paper on insect immigrants, Professor G. W. Herrick tells us that more than a hundred different species have come to America from other countries. On his return voyage from a visit to Europe he was interested to see on the breakfast-table one morning a lively female of the clover-leaf weevil, which had taken her passage from Cherbourg

to Southampton, and, had not the entomologist intervened, would probably have settled in the States like previous members of her species. How difficult it is nowadays to exclude these unobtrusive aliens, and how much harm they can do when they settle down! We need only mention the gipsy-moth, the San José scale, the brown-tail moth, and the Mexican cotton-boll weevil. The immigration continues, and Professor Herrick speaks of the recent American worries due to the appearance of the European corn-borer, the Oriental peach-moth, the Japanese beetle, the Asiatic beetle, and the twilight beetle. Of course the immigration is not all in one direction, for one recalls the Colorado beetle and the grape *Phylloxera*, both of which passed from America to France and proved exceedingly destructive. In view of these and a hundred similar facts, one realizes the folly of relaxing carefulness. It is not foolish to be afraid lest insects get the upper hand.

On the other side, however, account must be taken of man's conquests, and Professor Herrick closes his paper on a cheerful note.

From 1860 to 1870 there was great anxiety because of the spread of the Colorado potato-beetle from the Rocky Mountains to the Atlantic coast. 'Fifty years after, we are still growing potatoes more abundantly than ever, and the beetle is rarely a subject of inquiry on the part of the growers.' From 1890 to 1902 the San José scale threatened to ruin certain fruit crops. 'Twenty-five years after, we are not greatly concerned about the San José scale in New York State, and nowhere in the country does the insect seriously curtail the production of good fruit.' From 1900 to 1920 it was feared that the Mexican cotton-boll weevil was going to ruin cotton-growing in America. 'Yet in 1926 the United States produced by far the greatest cotton crop in all its history.' These are useful and encouraging statements, for while the three insects named are still causing enormous losses, man is gaining and keeping the upper hand. By putting brains into the business he is proving himself a conqueror. And to this every one, except the Father of Flies, will say Amen.

TRAPPING TSETSE FLIES.—Another of the crowding instances of man's conquest of difficulties is the recent success in trapping tsetse flies, which, as we have seen (p. 1369) are the carriers of sleeping sickness germs in man and of n'gana disease in stock. Unremitting endeavours have been in progress for years, but with little result in proportion to the energy expended. Attempts have been made to clear off vegetation from large belts so as to form barriers which the fortunately rather stay-at-home insects cannot cross, and in which they cannot breed. But this method is costly on a big scale. To another method, that of exterminating antelopes and other wild animals, supposed rather than proved to be the natural hosts of the sleeping sickness

organisms (*Trypanosoma*), there are several sound objections. The latest suggestion, that of large-scale trapping, has come from Mr. R. H. T. P. Harris, an entomologist working in Natal. The trap is a framework made of strips of wood and covered with dark hessian cloth. It is like the boards of a leafless book, hung with the binding down, and with cloth forming a flat top (six feet by three feet) from board to board. The 'boards' converge to about three inches apart, and there is a narrow slit along the 'binding,' which is hung about eighteen inches off the ground. The trap is thus somewhat triangular in cross-section, and the two vertical ends are closed with light cloth. To the flat upper-surface there is then fastened a transparent cage of wire gauze, so arranged that when the cloth is removed beneath, it rests on wires and opens into the hollow body of the trap by a non-returnable entrance. The whole trap is hung on the sunny edges of evergreen bush, each throwing a separate shadow. From a hundred to two hundred tsetse flies may be caught in one trap in one day, and it is not even necessary to kill them since they soon die of hunger and exposure.

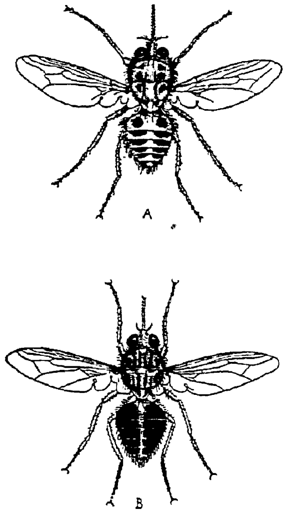


FIG. 466. TSETSE FLIES: A=male; B=female.

The whole point of these details from our present point of view is that the trap is a *scientific* one, that is to say, it is based on an understanding of the habits of the tsetse fly. Why do the insects enter the trap at all? The answer is that they hunt by sight, and search about in strong sunshine for game animals whose colour-tone is in contrast to the surroundings. It is unlikely that they perceive shapes as we do, but they are attracted to 'tonal contrasts'; and the trap with its shadow appeals to them as if it were an antelope! Darkish cloth was proved by experiment to be a distinct advantage. When the flies alight on an animal they seek out the under-parts, perhaps to get out of the way of tail or muzzle, and perhaps because the under-skin is softer for puncturing. Thus they explore the entrance to the trap, which is a foot or so off the ground. When they get into the interior and find nothing, they obey a light-seeking impulse or tropism and fly upwards to where the light comes in through the wire gauze. Then they are fatally trapped.

As a correspondent of *The Times* remarked, the adult seems to be the weakest link in the chain of the tsetse's life-history, and the

trapping, which is cheap and requires little attention, takes advantage of the fact that the adults do not travel far and are attracted to dark objects. Providentially, so to speak, they are slow to multiply and non-gregarious.

FIGHTING AGAINST MOTHS.—It is interesting to get from time to time reports of the measure of success that is rewarding the tactics pursued in combating destructive insects. Some egg-clusters of the gipsy-moth were introduced into the United States in 1869, and in twenty years the numbers had so increased that there was very serious defoliation of trees by the voracious larvae. There was rapid spreading of the pest from place to place. Now, however, there seems to have been successful eradication in Canada, and considerable reduction in the States. The methods used include the importation of natural enemies, the usual spraying and the like, and the setting up of a barrier zone twenty-five to thirty miles in breadth, which has greatly checked the westward spread of the gipsy.

In regard to another alien, the brown-tail moth, first noticed in Massachusetts in 1897 and soon spreading very rapidly and widely, preventive checks in the States have been even more successful than in the case of the gipsy-moth. The importation of natural parasites has proved very effective. There is, of course, nothing new in all this; we are referring to it simply because the experts have been recently reporting progress in an encouraging way.

AEROPLANES AND LOCUSTS.—We have read that, on the occasion of a plague of cockchafers in Switzerland in 1479, the insurgent beetles were summoned before an ecclesiastical tribunal at Lausanne. They were defended by an advocate from Fribourg, but, after deliberation, they were sentenced to banishment from the country. *O tempora!* How different is the atmosphere to-day! What hope there is in the growing habit of seeking counsel from science! We read the other day of the use of aeroplanes in Upper Egypt to dust preparations of arsenic and bran on the menacing swarms of locusts. The insects eat the bran and that 's an end of them. The method is expensive and obviously better suited for the desert than for populated areas. In Russia also there has been considerable use of aeroplanes against locusts, first to locate and then to poison what might be called the infantry — the 'hoppers,' which march along the ground before they have gained wings. The hopeful tactics are to kill off the locust infantry.

CHAPTER V

MAN AND PLANTS

Man's indebtedness to plants—Food plants—Fruits—Flavouring substances—Beverages, Narcotics and Stimulants—Drugs—Gums and Resins—Oils—Textiles—Vegetable colourings—Paper—Cork—Rubber—Timber.

MAN'S INDEBTEDNESS TO PLANTS.—In a time of urban evolution, mechanical invention, and synthetic chemistry it is well to be reminded of our indebtedness to the plant world. We depend on the flowers of the fields for our continuance from day to day. How can this be proved?

Even if we become very carnivorous, disdaining vegetable food and hardly ever touching bread, we cannot get rid of our dependence on plants. For the animals we eat are mostly vegetarian, and in a deep sense, as we have already said, all flesh is grass and all fish is diatom. In the long run everything depends on the green plant's power of **photosynthesis** (p. 1204), that is to say, on the upbuilding of sugar and other carbohydrates out of carbon dioxide and water. But besides carbohydrates and fats there are nitrogenous carbon-compounds or proteins, and for the supply of these essential parts of our food, like the casein of cheese or the albumin of eggs, we are always in the long run dependent on green plants. The most important chemical change in the world, because it is most fundamental, is the photosynthesis that goes on inside the green leaf.

Vitamins. Every one knows nowadays that a diet may be theoretically complete, containing carbohydrates, fats, proteins, some salts, and water, and yet be very unsatisfactory—because it does not include the accessory substances called **vitamins.** These are actual chemical substances that can be isolated in a state of greater or less purity. Out of cod-liver oil, for instance, with its rich content of the important vitamin A (whose absence spells rickets), it is possible to obtain an elixir a few drops of which go as far as a tablespoonful of the oil. An ounce of this will last a man all his life! On the other hand, it has been shown, in one case at least, that inefficient food may be made efficient, for growth and health, if it is irradiated with ultra-violet light, a remarkable fact which seems to suggest that the ultra-violet irradiation brings about the formation of a vitamin either in the food itself or in the body of the animal that eats it. But our introductory

note is simply this, that while man gets some of his vitamins from butter and eggs, milk, and other animal products, others can only be supplied by the cells of green plants.

But we are dependent on plants not only for carbohydrates, fats, proteins, and vitamins, we have to thank them for **fresh air.** When the earth's crust was still cooling there was a thick unbreathable air, with carbon dioxide, nitrogen, water-vapour, and dust-particles, but probably no more than a trace of oxygen. It is likely that all the free oxygen of the atmosphere has arisen in the course of the photosynthetic activities of green plants. Many reactions on the earth's surface use up oxygen, as in a volcanic fire, but is there any that liberates free oxygen except the splitting up of carbon dioxide in the green cells of plants? It is an important fact, then, that man and beast are kept breathing by the oxygen liberated by the chlorophyll-bearing plants.

The influence of **climate** on man is oftener under-appreciated than exaggerated. It has been a powerful factor in his evolution, sometimes as a spur to adventure, sometimes as a shelter making for relative stability, and often as a sieve eliminating certain types and retaining others. But climate is much influenced by vegetation, as is particularly obvious in the case of forests, which increase the rainfall and lessen the drought, besides affecting the winds and the weathering.

The original 'tentative men' (p. 1270) were forest-bred creatures, serving an apprenticeship first among the branches and then in the shelter afforded on the ground. During the arboreal apprenticeship served by the ancestors of *Homo* there were great gains in the direction of a free hand, stereoscopic vision, and brain-development; during the early hazardous life on *terra firma*, a premium was placed on wits and on social sympathy. Could man ever have got out of the wood, so to speak, if he had not sojourned for ages in the friendly shelter of the forest? The Garden of Eden was an Asiatic forest.

The old-fashioned poet who said that man has two worlds to attend him, had, as is usual with poets, a clear idea. He realized man's dependence on Nature. We have often to think of Nature as a stern winnower, but there are also many sides to her 'friendliness.' To put it less metaphorically, how many are the ways in which man, the Minister and Interpreter of Nature, has bent her to his purposes? Plants minister to man in giving him shelter and clothing, luxuries and aesthetic joys, fragrance and medicine, and in other ways more numerous than one can readily remember, not forgetting death. We need hardly say that the mistletoe was not the only plant that was forgotten when living creatures swore loyalty to man—the bacterial microbes were also overlooked.

In modern times, when the chemist has become more of a magician than ever, how many are our debts to plants! For from the

characteristic plant product, **cellulose,** he can make a hundred different things, some of them better dead. It is to be remembered, moreover, that the chemist is not merely a transformer, he is a versatile creator, building up the organic out of the inorganic. And thus with his synthetic alizarin he replaces the natural madder from the plant. In many cases the old dyes and scents are yielding or have yielded before the wonders of coal-tar derivatives, and the fields of flowers are shrinking. There are virtues, however, in some of the old products which were wrung directly from the plant; and we do not hear very much about synthetic rubber.[1] In any case, for the fundamentals that we began with, and for the higher joys of the garden, we shall always remain profoundly grateful to the plants. But it is time to pass to a more systematic survey.

Food Plants

The most obvious as well as the most important relation of plants to man is as food. This relation may be direct or indirect, but it is fundamental. For whether man actually eats plants or not, he must in the long run derive his nourishment from the plant world. He may eat meat or eggs, and drink milk, but to get these he must have grass and roots for his sheep and cattle, and grain for his poultry. Thus plants for feeding stock are one of the prime needs of human life. Even if man lives mainly on fish, his dependence on plants, though less obvious, is no less complete, for the fish may eat smaller fish, and these in their turn lowlier animals, such as crustaceans, but, however many links there may be in the chain, it will lead in the end to the simplest plants, without which neither animal nor human life would ever have been possible. These lower links are in Nature's keeping, but the plants with which we are here concerned are those in regard to which man has co-operated with Nature, seeking to improve them in the characters that best suit himself. Useful plants furnish not food alone, but textiles for clothing, timber for building, many valuable drugs, resins, and oils, and a great many other commodities without which civilized life is unthinkable. And the trees, shrubs, and other kinds of plants which yield these commodities man has taken into his own keeping and 'cultivated' for his own ends.

The most primitive bushmen in Africa and Australia gather the seeds of wild grasses, grub up roots with a fire-hardened digging-stick, and pick the sour fruits of the forest trees to tide over the long lean periods between the occasional successful hunting expeditions. At a

[1] Though this is merely due to the fact that, under present conditions, it is cheaper to grow rubber than to synthesize it.

slightly higher stage of civilization they—or usually their women—sow seeds and plant roots in a clearing round their camps, and thus secure a more constant and more satisfying supply, for any plant will improve to some extent in yield or quality if it be cultivated in fresh soil and with sufficient space.

We can imagine the men of a tribe going off several days' journey into the forest in search of game, and coming upon new or larger seeds and roots, which they tested and found satisfying and wholesome. They would bring these home to their women in the camp, who would sow some of them—possibly at first by accidental spilling, but later with deliberate prevision of next season's crop. In a year or two the crops would begin to get gradually poorer, and the tribe, not knowing how to prevent this, would strike camp and make at some distance a new clearing with virgin soil. This is and must always have been the beginning of agriculture; but it had progressed a long way beyond such beginnings before it resulted in any of the cultivated plants as we know them now. Yet without the testing and trying of all kinds of seeds, roots, fruits, and even leaves in the terrible struggle against hunger that all primitive peoples had to face, many of our most useful plants might never have been discovered at all. Travellers tell us how even now many savages collect all kinds of vegetables, even those known to be harmful, and cook them in many different ways in the hope of making them eatable. 'Dr. Hooker found the half-starved inhabitants of a village in Sikkim suffering greatly from having eaten arum-roots which they had pounded and left several days to ferment so as partially to destroy the poisonous properties.' Another traveller tells us that some savages watch to see what wild animals, especially monkeys, eat, so that they may not suffer too severely by experimenting for themselves. 'We probably owe our knowledge of the uses of almost all plants,' wrote Darwin, 'to man having originally existed in a barbarous state, and having been often compelled by severe want to try as food almost everything which he could chew and swallow.'

The great majority of our most useful cultivated plants are believed to have originated in the Far East, on the plains of Mesopotamia, and about the Mediterranean basin. A few, but these important, have come from South America, where there was an early civilization; but neither Australia nor New Zealand has contributed any. Precisely how cultivated plants arose we do not know. Many modern botanists believe that most of our cereals were derived not from one wild form but from several. They picture different peoples choosing the wild kinds that grew nearest to them for cultivation, selecting the finest plants each year for seed, weeding out the worthless ones, and preserving the new and promising variations that cropped up. As time went on, trade and intercourse between the peoples would increase, products would

be exchanged, and crossing of the different strains of plants would occur—at first, perhaps, by chance, but later with intention.

Nor do we know precisely when most of the useful plants took their present form, and, as in the case of the banana, which is seedless in its cultivated form, or the flax now in use, which has lost the power of splitting open its own seed-boxes, became incapable of continued existence without man's constant tending. But we do know that they were in use among the peoples of the ancient civilizations of the East—Assyria, Chaldea, and Egypt—and indeed without them these civilizations could never have come into being. If the human race had been forced to continue painfully gathering such foods as the wilds afforded, they would never have been able to congregate into cities, and would never have had time or energy to develop the arts at all.

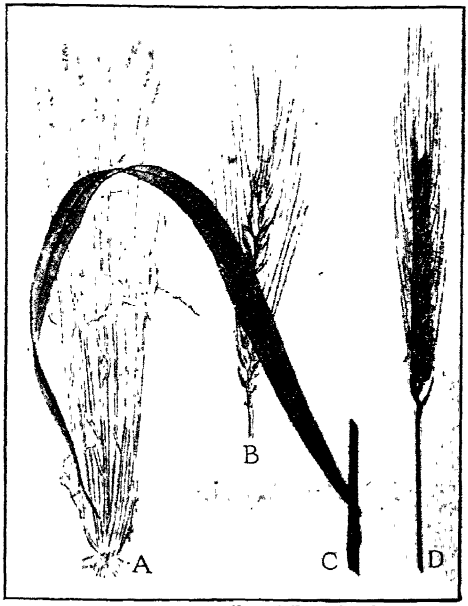
There is, however, direct evidence that cultivated plants were in use two to four thousand years B.C., and they must therefore have been evolved before the dawn of history. The ancient Egyptian monuments show representations of many food plants, and many seeds were found in the opened tombs of the Pharaohs. The seed called 'mummy-wheat,' a species not very different from our own, is well known, though it does not germinate; and another species was found in the Swiss lake-dwellings which were made in the Neolithic or flint-using age. To the Chinese emperor, Chin-nung, who lived about 2000 B.C., legend attributes the invention of the plough, and he is said to have each year himself sowed, with much ceremony, the first seeds of rice and four other grains.

But as to the antiquity of cultivated plants, we need no better evidence than that of the Old Testament, so familiar to us all. We have but to think of the mess of lentil pottage for which Esau sold his birthright; of the leeks, garlic, and onions of Egypt for which the Israelites sighed so bitterly in the wilderness; of the wheat and barley, the vines, figs, and pomegranates in the Promised Land to which they were journeying, and of the widow's cruse of olive-oil, to realize that the Israelites, like all the other peoples of the eastern Mediterranean, were far advanced in agriculture long before the Christian era.

WHEAT (*Triticum sativum*).—This is the most important cultivated plant in the world to-day, and from its history we can learn something of the way in which man, in co-operation with Nature, modifies a plant to his own ends, for the process of improving which began so many thousand years ago is still going on, with, as scientific knowledge increases, ever better results.

The earliest tombs of the Pharaohs in which 'mummy-wheat' has been found are about 6,000 years old, but there must have been a long previous history of cultivation. It is less than thirty years

since the original wild wheat, from which many races of our cultivated wheat have been derived, was found on the dry and rocky slopes of Mount Hermon. There it remains a truly wild plant, for it seeds and maintains itself, whereas wheat plants that had escaped from cultivation would have died out. There is no way of *proving* that Mount Hermon wheat is the actual ancestor of our modern races, but if the actual ancestor was not that particular form, it must have been very like it. It is a grass-like plant with short stems, drooping heads, and big seeds such as would catch the eye of an observant and hungry Neolithic man. It is also very variable, for quite a number of different varieties have been found. This is important, since it is only by selecting and combining natural variations that new 'races' can be made.



Royal Bot. Gardens, Kew

FIG. 467. WHEAT (*Triticum sativum*)
A Plant. B Head of Spelt Wheat.
C Leaf. D Head of Polish Wheat.

In the nineteenth century the process of selection became more subtle and less haphazard than it had previously been. In old days men set aside some of the seeds of a very fine wheat-field, but that field contained many different varieties mixed together. In the modern method of selection the heads of the best varieties were taken for seed, and the resulting plants kept by themselves to get a pure strain. When it is desired to intensify a particular quality the strain is crossed with another which also shows that quality in a high degree.

We can most easily understand the method if we follow the story of the famous 'Marquis' wheat. A sample of mixed mid-European wheat was sent about 1842 to a farmer in Ontario, and one grain in the sample produced three heads which attracted his attention by their fine qualities. He sowed the kernels of these heads by themselves, and got a variety which was named 'red Fife.' It had every desirable quality except early ripening. It was therefore used to

pollinate another variety which, though otherwise inferior, ripened a week earlier. After a long period of testing and rejecting, the variety known as 'Marquis' wheat was discovered and established in 1903; and this is now the dominant spring wheat in Canada and the United States, where, in 1910, the yield was 300,000,000 bushels.

So as to picture the vastness of the territories covered with wheat in these countries, we should realize that the reapers with their machinery must camp where they work, since the whole day would be wasted in going to and from the homesteads. And it is more profitable to burn the straw where it is cut, than to transport it over the immense distances to places where it could be utilized. Australia and Argentina have now immense plains under wheat, and these newer countries contribute a large proportion of the wheat used in Britain, though some still comes from Hungary, which, with Russia, has always been the chief wheat-producing area in Europe.

Why is wheat of such predominant importance that it, in particular, should have spread, within the last two centuries, from its original home, over every quarter of the globe?

The plants which are most useful to man as food are those which have stored the largest quantities of foodstuffs in a concentrated, palatable, assimilable, readily available, and easily transportable form. The plant's stores of nutritive material may be laid up in the seeds, as in wheat or peas; in underground stems, as in the potato; or in the fruit, as in the banana. But the plants that most fully meet the requirements stated above are found among the grasses, and the most generally cultivated of these, namely, wheat, oats, barley, rye, rice, maize, and millet, are grouped together as **cereals**—so called because gifts of the nutritive goddess Ceres. They have certain characters in common; they are all annuals, and therefore can be grown even where the winters are cold; their seeds contain the essential foodstuffs — protein, carbohydrate, and fat — in different proportions; and these seeds are dry, therefore ready for use, transport, or storage as soon as they are ripe. Wheat, oats, barley, rye, all contain more of the valuable nitrogenous compounds (proteins) than rice, maize, or millet; but the special importance of wheat is due to its sticky **gluten**, a protein which makes an adhesive dough, and therefore, by imprisoning the carbon dioxide generated in baking with yeast, gives rise to a light and easily digested bread. Varieties differ in the quality of their gluten. Most of those cultivated in Britain—and nearly every locality has one best suited to it—were 'weak,' that is, not sufficiently tenacious, and they had to be mixed with 'strong' varieties from Canada or Hungary to make satisfactory bread. But research in regard to this point is always being carried on, and 'strong' wheat can now be grown in England. Constant

experiment is also being made with a view to getting races immune to certain diseases such as rust.

Another of the advantages of wheat as a food plant is that it is relatively easy to grow, and it acclimatizes itself quickly. 'Winter' wheat, that is, wheat sown in autumn, is tolerant of a considerable amount of cold, and even of wet soil, provided there are three or four months with a temperature of 55–60° in which it can ripen. Wheat can also be grown in sub-tropical regions if it is at a sufficient elevation.

Charles Jones

FIG. 468. BARLEY (*Hordeum sativum*)

After the wheat is cut—and it may be stored in stacks—the first treatment is thrashing to separate the grain from the chaff and straw, both of which are of high value for bedding stock. Thrashing is now effected by complicated machinery, but it has gone through many phases, from beating by hand, treading by oxen as in Biblical times, and by the use of flails driven by horse- or water-power. The separated grains, now enclosed only in a thin coat, are afterwards milled or ground.

The grinding of flour was from very early times effected by friction between two stones, the lower of which was fixed, while the upper revolved upon it and crushed the grains to powder. The 'querns' found in Scotland, Ireland, and parts of Switzerland are examples of this kind of mill. In most of these there is a hole in the upper stone through which the grain was slowly poured, and a cavity at one side which held a handle for turning the stone. The mills became gradually more complicated, but up to nearly the end of the eighteenth century the double stones, of which there might be several pairs, were the essential features. Then a new machine with iron grinders was invented, and it was so much more efficient that the stones were soon superseded. The old type of mill ground the grain and its cuticle together, and though the flour could be separated from the 'bran' afterwards, some admixture of the latter was always left and darkened

the colour of the flour. But the new process of 'high grinding' crushed the grains first into granules, and complete separation of the two kinds was easy. 'Wholemeal bread' is made from mixed **flour** and **bran**, and is said to have a higher nutritive value than that made from fine white flour, from which both the husk and the 'germ' (or embryo-plant) have been removed. Bran separated from the grain is used as a basis for making cattle cake, and is also of value as a packing material.


Royal Bot. Gardens, Kew

FIG. 469. OATS (*Avena sativa*)

BARLEY (*Hordeum sativum*).—This was an important bread stuff before the cultivation of wheat became as widespread as it now is, and in regions not favourable to wheat-growing there is still regular use of barley bread in various forms, such as the 'bannocks' of Scottish country districts.

But for other purposes barley is still a very important crop. It has a wide range, being cultivated as far north as 70° in Norway; it germinates quickly and ripens early in any moderately warm climate, and there are several varieties suited to different localities. Thus in the bleaker part of North-east Scotland a hardy, early ripening form known as 'bere' is grown.

As a nutritious foodstuff the grain is used as pot-barley, or when the husk is removed, pearl-barley, for soups and puddings, or ground into flour for infants' and invalids' food. It has, however, no longer its ancient importance as human food, and is now grown chiefly for use in making malt to be used in the manufacture of beer and whisky.

OATS (*Avena sativa*).—This is said to be the most nutritious of all the cereals, but it, too, has been unable to compete with wheat as a bread stuff. The use of porridge in country districts where it was once the staple food is said to be diminishing, but it is undoubtedly increasing in favour elsewhere as an adjunct to breakfast, and oat-cakes, too, are

in general use. The grain is of the highest importance as a food for horses. It needs a moist climate and deep soil, and is grown in many of the higher parts of Europe, and in Canada.

RYE (*Secale cereale*).—This cereal is much grown in northern Europe and some parts of Asia. It will not thrive so far north as barley does, but it stands more cold than wheat, and it does not require a rich soil. Sandy ground and moderate warmth are its chief needs. Winter rye sown in early autumn is the most productive. The black bread of Germany and Sweden and Russia is made of rye, and rye biscuits have become popular in many countries.

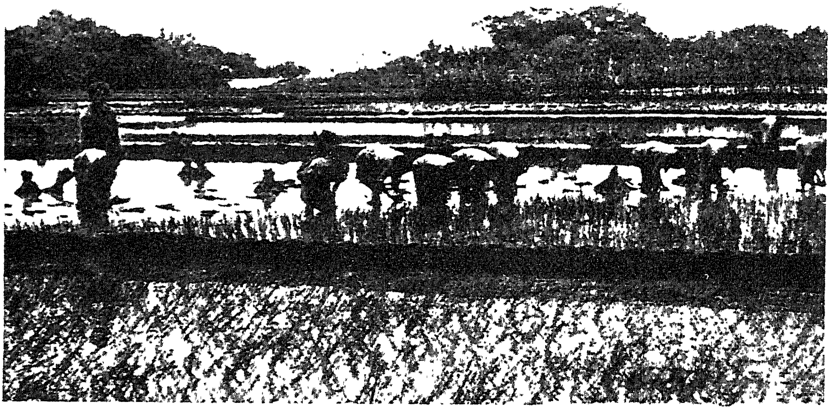
Nat. Hist. Museum

FIG. 470. RYE (*Secale cereale*)

RICE (*Oryza sativa*).—Though this cereal contains a smaller proportion of nitrogenous foodstuffs and of fat than any of the other cereals, it is the main, sometimes the sole, support of many millions of the people in Eastern countries, especially in China. In appearance it resembles wheat and barley, but its requirements and the methods of cultivating it are entirely different. It will grow only in tropical or sub-tropical countries, and it needs a large amount of water in the soil at certain stages of its development. Level land is necessary so that all the plants may get sufficient water, and therefore the plains and the deltas of the great rivers of the East are best suited for its cultivation. But mountain varieties are grown on terraced hill-sides at an altitude of 6,000 ft. In many cases artificial irrigation is indispensable, and from first to last the growing of rice means arduous toil. The soil, if not naturally marshy, must be flooded before the seed is sown, and when the young plants appear above the water they must be transplanted, and the water drained off. Water is necessary again at intervals, and since the amount given is of great importance, a flooding of the fields has usually to be secured. When the grain is ripe the water is drained off, the crop harvested, and the grain husked.

The crop is a very abundant one, for rice sends up many shoots and each shoot bears many ears, so that the proportion of yield to the acre

is higher than with any of the other grains in general use. Moreover, rice runs through its life-history so quickly that, there being no winter cold, it is possible to grow two crops in a year, or to use the land for other purposes when the crop has been harvested. Rice will grow on marshy land where no other grain could be sown, and it requires little in the way of manure. These advantages have to be set against the extreme laboriousness of the cultivation—and the unhealthiness too,



Royal Botanical Gardens, Kew

FIG. 471. TRANSPLANTING YOUNG PLANTS OF RICE
(*Oryza sativa*)

for the transplanting has to be carried out by workers standing almost knee-deep in muddy water. Rice is a crop suited only to a densely populated region, for there alone can sufficient cheap labour be found. The yield is sufficient to support a dense population and still leave some over for barter and export.

Rice by itself, however, though it might support life, does not suffice for energetic living! Its deficiency in nitrogenous compounds (proteins), of which it contains only 7 per cent as against 22 per cent in wheat, must be made up from other sources. Meat, milk, and butter are rarely obtainable in any quantity in regions naturally suited for rice-growing, and the usual addition is the soy-bean (q.v.), which supplies not only protein, but fat in the form of vegetable oil.

The disease of beri-beri is common in countries where rice is the staple food. It is believed to be due to a deficiency of **vitamins** (q.v.)

when the rice is 'polished,' that is, when the inner seed-coat is removed as well as the outer husk.

It is in Eastern countries that rice is of such enormous importance to human life, and it has been cultivated there from time immemorial. But in quite recent times it has been successfully grown elsewhere, and has become a valuable article of commerce. In southern Europe it is a good deal grown, especially on the plains of Lombardy. It was introduced into the United States in the seventeenth century, and there, on the great plains of South Carolina and Louisiana it flourished exceedingly. The method adopted is to sow the seed in broad trenches which can be easily flooded and drained again, to be reflooded before the crop matures. In the East, with its rice-eating peoples, a relatively small proportion is available for export, but Carolina and South Louisiana, with more advanced and economical methods of cultivation and harvesting, now send large supplies of the finest quality of rice to most of the markets of the world.

Whole rice, ground rice, and rice flour are much used in cookery; rice starch is economical and satisfactory for fine laundering, and 'broken rice,' of which there is always a good deal after the delicate process of polishing, is in great demand for poultry feeding, and also, mixed with the husks, for cattle food. The straw is used for plaiting.

'Rice-paper,' used for colour-printing, especially in China and Japan, has no connection with the rice plant; it is the finely sliced and pressed pith of the rice-paper tree, peculiar to Formosa.

MAIZE (*Zea Mays*).—This cereal, often called 'Indian corn,' is of great importance as a foodstuff, especially in tropical and sub-tropical countries. It had its original home in tropical America, for it was certainly not known in Europe before the time of Columbus, and grains of some unidentified variety have been found in some of the ancient tombs of Peru. Although maize has some characters in common with the Mexican cereal teosinte (*Euchlaena mexicana*) no wild plant that can be regarded as the original ancestor of the cultivated maize has ever been found.

One of the noteworthy characters of maize is its extreme **variability.** More than 300 varieties are known. The smallest is only about three feet in height, while the tallest rises to eighteen feet; the grains of the largest variety may be ten times the size of those of the smallest, and the colour of the seeds may be white, blue, or red. The male flowers of maize are borne as feathery tufts at the end of the stalk; the female flowers spring from the leaf-axils below. When these female flowers mature they form the well-known 'cobs' with close rows of seeds, and long silky styles hanging out at the tips.

In tropical and sub-tropical regions maize can be grown up to a height of several thousand feet. Many different varieties are

cultivated in America, the choice being determined by the climate and soil. ' Pop-corn ' is a kind in which the starch content is large relative to the husk, and when it is heated it dries, swells, and ' pops.' The seeds of maize are almost as rich in protein as those of any other cereal except wheat, and they contain more fat than any except oats, but, as they lack the particular protein called gluten, maize flour by itself does not make a light bread. A very nutritious, if rather coarse bread used in New England, is made by mixing it with rye. ' Johnny-cake ' is made from maize. The 'corn,' as it is always called in the United States, is used in many ways, whole or ground. In rough granules it is known as **hominy**, and is much used for porridge and puddings. Finely ground and freed from the germ (or embryo-plant), it forms the cornflour and the cornflour starch of commerce.

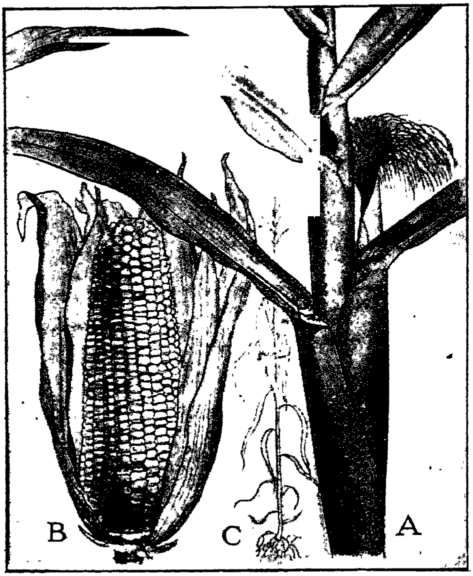


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FIG. 472. MAIZE (*Zea Mays*)
A. Young cob with silk. B. Cob. C. Plant.

SWEET CORN (*Zea saccharata*) is a different variety, grown rather as a garden vegetable than as a field crop. It is cooked and served in the cob, or the grains may be boiled in milk. The young stalks thinned out are served as a vegetable in the same way as asparagus. The sweet syrup extracted from the stalk may be made into glucose, or be distilled to yield ' chica ' or Peruvian beer. Both species are often cut green, or dried for winter fodder.

Maize is largely grown in India and in Africa, where it supplies the Kaffir with his mealies. In Europe it ripens its seeds only in the south, but it is grown in other parts as fodder, and is very valuable because it will thrive in regions, like Brittany, where clover and lucerne do not flourish. In Australia the maize crop was five times as large as the wheat crop not much more than a century ago, but the proportions have altered greatly. Maize still holds an important place, however, for its yield is very high in suitable districts such as the alluvial flats of New South Wales. It is often cut green for fodder

and ensilage, and is also sown to follow timber, or when sour land is being cleared for dairy-farming. Wherever it is extensively grown subsidiary industries have sprung up. Thus there are factories for making glucose, which is used in confectionery and jam-boiling, and in dyeing and tanning; for extracting the oil from the germ separated in making cornflour and starch, and for utilizing this oil in making soap, and even rubber substitute. The residue from these industries makes a very nutritious cattle cake.

MILLET.—This name, which means 'thousands,' is applied rather to a group of prolific grasses cultivated for their edible seeds than to a particular species. The common millet (*Panicum miliaceum*) is indigenous in the East Indies, but is now cultivated in most warm countries. Indian millet or 'durra,' *Sorghum vulgare*, is a staple crop, more important to the natives than even rice. The varieties cultivated in Europe, South Germany, Hungary, and Italy have very small seeds but a great many to the head; they are grown partly for culinary purposes, but chiefly for export as food for poultry and for cage birds.

Nat. Hist. Museum

FIG. 473. MILLET (*Panicum miliaceum*)

Millet is largely grown by Kaffirs for food and by colonists for feeding stock. As 'Kaffir corn' it was introduced into Australia, but it has been superseded by wheat. A sweet variety is sometimes cultivated for sugar. Millet is also grown for fodder, but it is said that at some stages there is risk of cattle-poisoning from the prussic acid in the young plant.

SUGAR-CANE.—As we have noted, several of the cultivated grasses lay up their carbohydrate reserves in the form of a sugary sap within the stem. Sugar-cane (*Saccharum officinarum*) is a giant among these sweet grasses, and it is cultivated in all the warmer countries of the world for the sake of its sugar alone. It thrives best in moist warm areas, but it is hardy and adaptable, and will grow 'in light and heavy soils, under copious or scanty rainfall, in humid and exposed

and wind-swept situations.' Canes about two inches thick and from ten to fifteen feet high spring up from the stock each year. They are cut before flowering, and pressed between rollers to extract the juice from the soft inner tissues of the stem. Propagation is usually by slips.

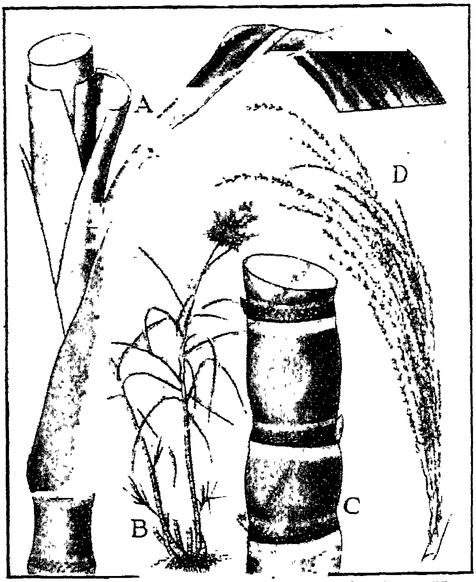

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FIG. 474. SUGAR-CANE (*Saccharum officinarum*)
A. Leaves. B. Plant. C. Cane. D. Flowers.

Sugar-cane came from the East and was introduced into Barbados by the Spaniards, and from there its cultivation spread to all the West Indian Islands, and to the suitable districts of the mainland of America. In the early days when slaves were available, enormous fortunes were made by sugar-growing, but when that supply of labour came to an end the industry had for a time a difficulty in holding its own. As the use of sugar increased the industry revived, though it did not become quite so prosperous as before. One of the reasons was that a great part of the sugar now used in Europe comes from the **sugar-beet** (*Beta vulgaris*), which lays up its sugary reserves in a fleshy root. Selection towards increase of the sugar content of the roots is still in progress.

PEAS, BEANS, AND LENTILS.—Next to the grasses as food plants may be ranked those grouped together as pulse—the peas, beans, and lentils. They form a section of the leguminous or pod-bearing order of plants, and their great value lies in the richness of their seeds in **proteins** (nitrogenous carbon-compounds). The original home of most of the species was in Mediterranean lands, and they are still of great importance there; but one species or another is now cultivated almost everywhere, for they differ greatly in their requirements as to climate. They all have the great advantage that they will not only grow in soil that is poor in nitrogen, but they will leave it richer than they found it. The reason for this is that their root-hairs are invaded by certain soil **bacteria**, which multiply rapidly in the root and cause the forma-

tion of small **tubercles** or nodules, within which they live in ease and plenty. These peculiar bacteria have the power which no ordinary plant possesses, of absorbing and fixing the free nitrogen of the air (which is of course also present in the soil), and the plant is able to make use of the organic compounds thus obtained. The bacteria in their turn get the other elements of their food from the sap in the tissues of the root. When the crop is harvested the rotting roots liberate the nitrogen within them, and so enrich and prepare the ground for its next crop. 'Thus it is that the lupine can conquer the shingle, the whin the heath, the broom the roadside, and the rest-harrow the dune.'

Charles Jones

FIG. 475. SUGAR-BEET (*Beta vulgaris*)

THE PEA (*Pisum sativum*).—The well-known garden pea has many varieties, short and tall, early and late, smooth-seeded and wrinkle-seeded, and the varieties best suited to each locality, and even to each garden, must be grown if the best results are to be obtained. The field-pea or 'tares' (*Pisum arvense*) has a single red flower on each stalk. Lime or chalk in the soil is essential to its successful cultivation. It is grown partly for human food and is sold as dried peas, split peas, or pea flour. The last makes among other things the very satisfying 'pease-brose' of rural Scotland. But the chief use of the field-pea is as cattle food, and it is usually cut before the seeds are quite ripe, for the green 'haulm' is even more nutritious than hay.

The chick-pea or gram (*Cicer arietinum*) requires warmth for its prosperity. It is much used in the East and in the south of Europe; but a too prolonged or too exclusive diet of chick-pea is said to have very serious results to health because of the amount of oxalic acid the plant contains.

BEANS.—The common or broad bean (*Vicia Faba*) is grown as a garden vegetable. The seed is very nutritious, though to some constitutions difficult of digestion. A variety is grown in fields, and its

seeds are broken up to form an excellent food for horses. A 'bean-feast' means a very satisfying and somewhat stimulating feast.

Many different kinds of bean are used in the East. They were known in China before the Christian era and were later introduced into India and Japan. The **soy-bean** (*Glycine Soja*) is one of the most valuable kinds, because the seed is extremely rich in oil. It is used either as a food by itself, or to make a nutritious and savoury sauce which is an excellent adjunct to the rather insipid diet of rice.

French, kidney, or haricot beans (*Phaseolus vulgaris*) came from South America, and were not known in Europe till after the time of the Spanish explorers. They are much less hardy than the common bean, being quite intolerant of frost. They are often eaten in the pod, and may be used dried, fresh, pickled, or simply salted. In southern Germany and other parts of Europe every family has its barrel of salted beans, the whole strength of the household, down to the little children, being turned on for a day or two to preparing the supply for winter use.

THE LENTIL (*Lens esculenta*).—This is a food plant of great antiquity, believed to have been first cultivated in the lands bordering the eastern Mediterranean. It was in use in very early times in Egypt and Syria, and in these countries it is still made into *pottage*. Or it may be parched, that is, roasted dry in a metal pan over the fire. The lentil is also grown in southern Europe, and the seeds, believed to be the most nutritious of all the **pulse** group, are used for soups, for lentil flour, and as the basis of many prepared invalid foods. They are the great stand-by of vegetarians, and a useful resource whenever meat and fish are difficult to procure.

THE PEA-NUT.—This plant, also called ground-nut or monkey-nut (*Arachis hypogaea*), is, in its mode of growth, an interesting member of the leguminous order. It came originally from South America, for it was in use in Brazil and Mexico before the Spaniards first went there, and it was not known in the Old World till after the discovery of the New. It is now cultivated in the southern states of North America, in India and China, and very extensively in both East and West Africa. It is used, especially in America, as a dessert nut and in confectionery, but by far the larger proportion of the whole world's crop is used for the production of a fine salad oil which rivals olive-oil in quality, and has partly displaced it. The residue, after the oil has been expressed, makes one of the most nutritious oil-cakes for cattle.

In Africa the seed is sown just before the beginning of the rainy season in early July. The young plant appears in a week, and it is flowering in about six weeks. After pollination the flower bends over, and the stalk below the pistil grows rapidly, thus forcing the seed-box

down into the ground. So this is a plant that sows itself. When it is completely buried the seed proceeds to develop, and it has completed its development by late October. If left alone it would sprout, but the seeds are dug up out of the ground with a suitable pronged instrument and, still attached to their stalks, are piled in heaps and left to dry. The work of digging up and picking off the so-called nuts is almost entirely in the hands of women and children. The nuts are packed into sacks and carried to the nearest marketing centre on the backs of camels and donkeys, which are fed on the dry leaves and stalks. So the whole pea-nut business is run on very economical lines.

LUCERNE (*Medicago sativa*).—This leguminous species, called alfalfa in America, may be taken as a good example of a food-plant whose importance to man is indirect. A fodder plant like clover, it thrives best in a warmish dry climate. It is not much grown in England, but more on the continent of Europe. It did not reach California till the middle of the nineteenth century, and now over two million acres are covered with it in the west of North America. It has been of inestimable value as a pioneer plant for the great fruit-growing enterprises of California and Arizona, and also more generally in reclaiming desert land. It is a very accommodating plant. Thus it will grow on land that has just begun to be cultivated. Having very long roots it requires no great accumulation of water at one spot. It does not suffer from the alkali in the desert soil. It comes up year after year unless killed by severe frost. It will go on growing all the year round, and thus yields several crops of valuable hay in the year; and finally, it will leave the soil richer (by the captured nitrogen), and better prepared for another crop, than when it was put in. There are many varieties, some less tolerant of cold than others, and the United States Government is continually experimenting to find the varieties most suitable for each area, for 'the more alfalfa each particular field can be made to grow, the more beasts the farmer can rear and keep. The more beasts he has, the more manure he gets for his land, and the more labour to plough his land. The alfalfa is the base on which stands the whole pyramid of his prosperity.'

THE POTATO (*Solanum tuberosum*).—This familiar species has indeed been a boon and a blessing to men, but it has some near relatives of worse than dubious characters. The bittersweet (*Solanum Dulcamara*), that twines on our luxuriant hedges, is a fellow-species with distinctly poisonous properties, and even worse is the fruit of the North African 'apple of Sodom.' Not far off is the deadly nightshade (*Atropa Belladonna*), with its potent poison, **atropin.** The fact is that the leaves and fruits of the potato contain a good deal of the poison called **solanin.** To tell the truth, the same toxin is found in the unripe tubers, but it seems to disappear in the course of growth. Yet the

egg plant is a species of *Solanum* with edible fruits, and the tomato is another. Also belonging to the family is the tobacco plant, which is, of course, beyond praise.

Who discovered the potato? This very interesting question has been answered in a scholarly way by Mr. William E. Safford, who comes to some important conclusions.

It is probable that the small tubers of an unknown wild potato were first utilized in South America, in the Andean region, long before Columbus's days, and that the eventful cultivation began very early. Dried-up specimens and terra-cotta representations of potatoes are found in the ancient cemeteries in the desert lands on the Pacific coast of Peru and northern Chile. There seems no doubt that the potato is Peruvian in origin and not Virginian. No genuinely wild forms are known.

When Sir John Hawkins provisioned his ship at Santa Fé, on the coast of Venezuela, the naked Carib Indians gave him 'potatoes.' But these were sweet potatoes (*Ipomoea Batatas*), belonging to the *Convolvulus* family, which Columbus and his companions had greatly enjoyed when they arrived in the New World in 1492.

It was the botanist Gerard who first figured the true potato, *Solanum tuberosum*, in his *Herbal* of 1597; but he unfortunately appropriated for it the name 'potato,' which belonged to the quite unrelated 'sweet potato.' Confusion was increased by the common use of the tubers of the 'openawk' (*Glycine Apios*), which formed a staple food of the Indians from the Gulf of Mexico to the St. Lawrence River. It belongs to the pea order (*Leguminosae*), and its tubers are often the size of walnuts.

One of the pieces of information impressed on us in our childhood was that Sir Walter Raleigh brought the potato from America to Britain about 1588, but the courageous Mr. Safford tells us that there is not a particle of evidence that Sir Walter ever saw a potato in America. If he brought anything home it was the openawk.

The same seems to be true in regard to Sir Francis Drake, to whom, as alleged introducer of the potato (about 1580), a statue was erected in the town of Offenburg in Baden. The fact that the statue holds a true potato in its hand does not seem to have impressed the American sceptic, but he admits that Drake saw true potatoes in Chile in 1578.

According to Safford's learned inquiry the first published account of the potato is to be found in the journal of Cieza de Leon, who found it in 1538 under cultivation around the high-lying villages of Colombia and Ecuador.

In 1578 Drake observed the use of potatoes by the Indians of southern Chile, and in 1587 Thomas Cavendish got bags of them for his ship from the same locality. They were soon in regular use on Spanish ships,

and it was probably in this way that they came to Europe. As we know through the botanist Clusius, they were in cultivation in Italy about 1585.

For many years the potato was little more than an exotic curiosity in Europe, the reason being that the tubers were relatively small. It probably began to come to its own in Ireland, where food used to be scarce. 'It served for breakfast, dinner, and supper,' and also for making the spirit called 'poteen.' It was an Irish field crop before 1663, a year of great dearth in Great Britain and Ireland; but it was not a field crop in England till later, and not in Scotland till 1739.

It seems certain, according to Mr. Safford's researches, that the potato was not introduced into Ireland from America, but the other way round. It was brought to the United States by Irish immigrants in 1719.

Hundreds of varieties of potatoes are now known, some of them arising by crossing different strains and others by selecting variations that crop up.

These new departures are started from seed, but after the first generation of seedlings there is the usual propagation by planting out the tubers or pieces of tubers that have an '**eye**' or bud. It has long been known that potato varieties tend to degenerate, and it used to be supposed that this was due to continued propagation by tubers and the consequent absence of the sexual process necessary for the setting of seed. It is now known that the degeneration of the potato is due to the attacks of one or more **virus diseases** (q.v.). These are transmitted by leaf-sucking insects, and spread rapidly in warm regions, such as the south of England, where such insects are numerous. In the cooler northern parts of Scotland the insects are much less numerous, potatoes remain free from virus disease and do not show any signs of degeneration. It is for this reason that the best seed potatoes are raised in Scotland. Considerable success has also attended the efforts which have been made to breed varieties immune to various diseases caused by fungi.

THE YAM (*Dioscorea*).—This tuberous plant is much used in tropical and sub-tropical countries. There are several edible species, with twining annual stems above ground, and underground tubers which may reach a very large size. These **tubers** are rich in starch and are cooked as a table vegetable. The best kinds are the winged or white yam (*Dioscorea alata*), the negro yam, and the cush-cush or yampi. The negro yam forms a large part of the food of many tribes in Africa, and there are several varieties much used by the natives of India. The flesh of nearly all the species is sharp and bitter, but this defect is remedied by cooking, for they become mealy and pleasant. **Axillary tubers** may be formed on the above-ground

part of the stem, and these too may be eaten. The plant is propagated in the same way as potatoes, by planting pieces of tuber that bear 'eyes' or buds.

THE TARO (*Colocasia antiquorum*).—This is another tropical plant that stores large reserves of starch in underground tubers, budded off laterally from the main stem. It is a native of the East Indies, but is widely cultivated elsewhere. It thrives best on light clay or sandy soil, and needs much water during growth. It is cooked like potatoes, and propagated in the same way. The tubers form the principal food—supplemented by raw or dried fish—of the natives of the Sandwich Islands, who make it into a paste they call 'poi.' The broad, heart-shaped leaves of the taro, stripped from the ribs, are cooked and eaten like spinach. Uncooked they are poisonous.

Royal Bot. Gardens, Kew

FIG. 476. SAGO-PALM (*Metroxylon Saga*)

ARROWROOT.—This is a pure starch obtained from the roots of various plants. Bermuda arrowroot, one of the most highly valued kinds, comes from *Maranta arundinacea*, and in some of the West Indian Islands the cultivation of this plant stands next in importance to that of sugar. The roots are dug up, dried, ground, washed, and spread out on wire frames of different meshes. As it dries, the powder drifts down through these, and is then packed in barrels for export. **Brazilian arrowroot** is prepared from the tuberous roots of *Manihot utilissima*, and is also known as **mandioc** or **cassava** meal. **Tapioca** is prepared from the same root by drying the washed powder on hot metal plates until the starch grains burst, then stirring them with a

glass rod so that they agglutinate into small lumps. **Portland arrowroot** used to be made from the roots of the common British ' cuckoopint ' (*Arum maculatum*), but the difficulty of getting rid of the poisonous juices of the plant was so great that the utilization of this species had to be abandoned. But there are several related plants in warm countries that supply a safe and convenient food, e.g. *Curcuma angustifolia*, nearly related to ginger, has fleshy roots which are dried and powdered. The powder is known as **East Indian arrowroot.**

SAGO-PALM (*Metroxylon Saga*).—The edible part of the sago-palm is the great mass of pith within the relatively thin-walled stem. The tree, of which there are two species, grows abundantly in many islands of the Indian Archipelago. It takes about fifteen years to come to maturity, and is then cut down and divided into lengths to facilitate the digging out of the pith. Dr. Hose describes the graceful forests of wild sago-palms which adorn the slopes of the Bornean hills, and tells us that the native tribes never travel without the sieves and mallets necessary for preparing the powder before making it into the porridge which forms an important part of their food. The powder is also dried and baked into biscuits.

These wild trees, which form great forests in New Guinea also, contain an abundant reserve of food, useful to fall back upon when the rice crop is insufficient. For export purposes the starch grains of the pith are burst by contact with hot plates, and are thus granulated or ' pearled.'

Fruits

We have noted that there is very often a concentration of protein, starch and oil in seeds of plants, and a store of farinaceous foodstuff in roots or underground stems, and that the inhabitants of all temperate and tropical countries depend to a large extent on these sources for their nourishment. Fruits, being mainly composed of sugar and water, are less important as an actual food-supply in temperate countries, but they are of great value because of the accessory food factors (see VITAMINS) and the mineral salts which they contain.

As the time for seed-forming draws near, there is a great accumulation of sugary sap in the stem. This is of no direct use to the plant, but by this time it is not required elsewhere, for growth and leaf formation are over for the season, and the sap can be used for the development of the fruit. The sweet and juicy pulp, the skin of which is usually brightly coloured when ripe, attracts birds, fruit-eating bats, and monkeys. The seeds are swallowed with the fruit, but they are generally protected by a hard or tough outer covering which resists digestion in the food-canal of the bird—for birds are the most important

agents in the dispersal of seeds. They are transported and dropped, possibly at a considerable distance from the parent plant, and often in places where they may find space and suitable soil to start a new growth.

Man has taken many wild fruits into his own hands, and cultivated them with reference to his particular needs. In so doing he has in many cases succeeded in suppressing the seeds altogether, and thus making the whole fruit edible, e.g. in the banana and in some varieties of orange. One result of this is, that the tree or plant is no longer capable of maintaining its existence in a natural state, for new plants must be started by means of cuttings, suckers, or grafts, and this requires human agency.

In north temperate countries the small bush fruits—gooseberries, currants, raspberries, strawberries, and the like—succeed best and are of great importance. The apple, too, stands a good deal of cold, though it is apt to suffer from late frosts when the fruit is beginning to set. Most varieties of apple—and they run into thousands—are derived from the common crab-apple, which is indigenous to many parts of northern Europe and Asia, but is itself too harsh and sour to be of much use as food.

New varieties of apple are obtained from seed, and have been utilized to suit many different conditions. Once obtained, however, they are propagated by grafting on a hardy stock. Apples are grown throughout the British Isles, but in any considerable quantity only in the southern counties, where many are used for the making of cider. A great proportion of the apples used in Britain comes from North America and Canada, especially from British Columbia, where apple-growing has become a vast and valuable industry.

Pears and plums are also grown in temperate countries, but the finer qualities require a good deal of sun to ripen them thoroughly. But it is in tropical and sub-tropical regions that fruits reach their highest perfection, and are of most importance in the lives of the inhabitants. Let us look at a few examples in more detail.

BANANAS (*Musa Sapientum*).—Probably not many people have any picture of a banana plant. We accept the fruit as a gift from the gods, but did the big bunches grow high up on a tree, like dates, or near the ground, like pineapples, or between the two, like grapes? So we were very much pleased not long ago to see a banana in flower in the Botanic Gardens in Aberdeen, and to watch the fruit forming and swelling. The plant was about eight feet high, but it would be gross flattery to call it a tree or even a shrub. It seemed to us to be mostly leaf, for the pillar that rose from an underground stem and bore the magnificent crown of foliage was really made up of leaf-bases enswathing one another. The glossy, narrow-stalked leaves,

shaped like the blades of oars, were over a yard long, and resembled those of some palms. Indeed, it might not be very far wrong to say that the banana plant is a herb that is trying to be like a little palm tree. From the centre of the crown of huge leaves there rises a long spike, with female flowers at the base and male flowers higher up. The spike really rises from the underground stem, and passes up the pillar made by the enswathing leaf-bases. In almost all the edible bananas the bunch of flowers becomes pendulous. We have seen some bunches of fruit in Africa that weighed thirty pounds and this is far from being the maximum. The banana is anything but niggardly.

Royal Bot. Gardens, Kew

FIG. 477. BANANA TREE (*Musa Sapientum*)

When the fruits are ripe the visible parts of the plant begin to die away, and eventually nothing is left above ground. The banana plant is one of the many that retreat periodically into a subterranean stem. This gives off new buds or shoots, which may be used to start fresh plants. These grow quickly, and may be bearing fruit in a couple of years. In warm moist climates the cultivation of the banana is almost too easy, for little attention is needed after the planting, except that the groves must be kept clear of smothering competitors. Believed by many to have been first cultivated in Asia, the banana is now grown wherever the conditions of climate and soil are suitable. Thus there are great groves in Queensland, yielding over 2,000,000 bunches in the year. It is perhaps in the Canaries that the selective cultivation has been most careful and most generously rewarded.

As is so often the case, the wild ancestor of the cultivated banana is uncertain, for there are several wild species. But it is not likely to

have been very different from a plant that grows freely in African forests, and is marked by its large bitter seeds and its thin covering of flesh. This is a good instance of evolution; man has persistently cultivated from variations in the direction of seedlessness, fleshiness, and palatability. Just now and again one comes across a seed the size of a bramble pip—the past reasserting itself after long ages.

Speaking of palatability, we must admit that there are bananas and bananas. We do not agree with the continental zoologist of distinction who ate his first banana in our presence about forty years ago and compared it to pomade; nor with the others who liken the fruit to 'cotton-wool and Windsor soap,' but we must admit that some of those imported into Britain are distinctly raw. This is particularly true of the 'green' varieties that go on ripening after they are cut. In many cases they turn out well, and they are readily imported without injury; but if they are cut too soon the natural processes of fermentation do not set in, and the result is very crude. The perfect fruit is a very different article, and cannot be obtained unless the ripening is completed or well advanced on the plant itself. As visitors to the Canaries and similar places know, the 'golden' skin becomes thin and the flesh becomes translucent and pulpy, and of exquisite flavour. We need to know these 'golden' bananas to appreciate a traveller's description of those he picked in Borneo: 'Rich and luscious as new honey, leaving an aroma in the mouth like that produced by ripe filberts and dry old port.' That is the proper spirit!

But the fact is that, while one has to distinguish between the farinaceous and the saccharine varieties of banana, the fruit has proved one of the nutritive treasures of the world. It has been asserted that more people live on bananas than on any other one thing, but we have heard the same thing said of rice. In any case it is safe to say that several hundreds of millions of our fellow-creatures live on bananas. A frequent treatment is to boil the mealy variety into a paste, which is eaten, if possible, along with something more savoury. The family sits round the cook-pot, with hands ceremonially, if not carefully, cleansed. Each puts his fingers into the pot, scoops out some paste, moulds it into a little ball, dips it in the precious sauce, and conveys it skilfully to his mouth. In some cases the bananas are dried and ground into 'plantain meal,' which is made into a paste flavoured with lemon juice.

Professor Scott Elliot remarks that the banana differs from almost every other fruit in being both 'rice and prunes'; that is to say, it is very nutritious and at the same time very palatable. He also notes that bananas will produce nineteen and a half tons of dry fruit per acre, which is about forty-four times the yield from potatoes, and one hundred and thirty-three times that from ordinary wheats. We

have already referred to the easy cultivation, which is such a contrast to that of rice. And besides yielding wholesome food, the banana can be used as a basis for more or less unwholesome drinks. The broad leaves serve for thatching and the leaf-bases contain a fibre used in making ropes and even fabrics. The fibre of a Philippine species, *Musa textilis*, forms the well-known **Manila hemp.**

It is evident, then, that the banana comes as a boon and a blessing to men, and one looks round instinctively for the seamy side. It is not far to seek; it is sociological. Just as there is a sociological aspect of wheat and of rice, so there is for the banana. It makes the bread-and-butter problem too easy of solution. In any normal year the native can get plenty of food with very little work; so he becomes incorrigibly lazy. Banana-eating races are apt to be unprogressive, not merely as regards agriculture, but in other ways as well. The banana has a pleasant name, *Musa Sapientum*, and the closely similar **plantain** is sometimes distinguished as *Musa paradisiaca*, but let us be thankful that we do not live on bananas and that our ancestors didn't.

ORANGES AND LEMONS.—These are among the most beautiful things in the world. Pyramids of oranges in the fruiterer's shop window are familiar enough, but we need also to see oranges in bulk, in great heaps, like potato-pits, in the market-place of a town in an orange-growing district. Even more beautiful, however, are the groups of individual oranges and lemons in the gardens, especially when one looks up through them from the walk, or down on them from above. The colours of the fruit and the foliage are in harmony, one harmony for oranges and another for lemons.

The species of *Citrus*, including **lime** and **mandarin** and **grape-fruit** as well as oranges and lemons, are all natives of the Far East, and it is believed that the Arabs have the credit of bringing the orange and the lemon to Europe and Africa. That was many centuries before their introduction to Florida and California. What a golden gift to bring!

The common **sweet orange** (*Citrus Aurantium*) is very interesting to biologists because of its many varieties. In the course of ages of cultivation many sports have arisen, and these, kept by themselves and selected in the usual way, have become true-breeding races. These races may be crossed by artificial pollination, and more varieties appear; and after the seedlings have grown for two or three years they are often grafted on to a vigorous, well-established stock. Thus oranges have become better and better every century—sweeter, juicier, more resistant to the weather and to enemies. Some of the varieties are very subtle. Thus one has leaves with the aromatic quality so highly developed that the leaf-cutting ants, which are very destructive in South America, will not touch them. The blood orange

is just a colour variety like the red gooseberry. The seedless variety is a good instance of a sport that would not last long in Wild Nature! Very important for both consumer and cultivator is the lengthening out of the fruiting season by using different varieties. It now lasts, indeed, from early November to late June.

The **bitter** or **Seville orange** (*Citrus Bigaradia*) is smaller and redder than the sweet orange, and is grown chiefly in Spain and along the coasts of the Mediterranean. Large quantities are imported to Britain after the New Year for marmalade-making. On the Riviera the large and fragrant flowers are used fresh for making **scents,** as may be well seen at Grasse. Others are dried and exported to help in the manufacture of eau-de-Cologne. Some of the fruits in the Riviera are allowed to ripen, and they are exported to form a flavouring for liqueurs; and even the secretion of the leaves may be distilled for the same purpose. It is interesting to note the variety of the utilization—marmalade, scent, liqueurs—and this is by no means exhaustive.

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FIG. 478. ORANGE IN FLOWER (*Citrus Aurantium*)

The **common lemon** (*Citrus Medica,* var. *Limonum*) is a delicate cousin of the orange, and it is only in the most sheltered parts of Europe, as in Italy and Spain, that it will flourish. In its fresh state it is a familiar accompaniment of fish and of oysters, and it ought to be, as it often is, the basis of lemonade as well as of lemon squash. Essence of lemon is extracted by distilling the peel in alcohol; the pulp yields **citric acid**; and the raw lemon juice is used for medicinal purposes. The lemon has a near relative, the **citron,** with a very thick skin, which is familiar as 'candied peel,' while the juice is also used in confectionery.

Of great importance to mankind is another relative—the **lime** (*Citrus Medica,* var. *acida*), which requires a tropical climate. It is chiefly cultivated in the West Indies, especially in Jamaica and Montserrat. It is like an orange in its flowers and shoots, like a lemon in its fruits. Of course they are all near relatives. The lime has come as a boon and a blessing to men, for it includes a very effective anti-scorbutic ('against scurvy') vitamin. Lime juice, as all the world knows, has practically put an end to scurvy on board ship—a fine

instance of science for life and man's conquest of a horrible disease. All the citruses are fragrant, but the finest of all is the **bergamot** (*Citrus Bergamia*), now being greatly encouraged in French colonies in Africa. As we can readily verify, the leaves and the skin of the fruit in the orange and lemon genus (*Citrus*) contain little nests of cells which secrete droplets of clear oil into a central cavity. There is no certainty as to the rôle of this oil in the internal chemical routine of the plant; that its presence may in some cases discourage insects is undoubted. But the secondary utilization is not so interesting scientifically as the primary physiological significance, which remains obscure. We must be content at present to call the aromatic oil a by-product.

The **mandarin** (*Citrus nobilis*) is an importation much more recent than the orange or the lemon. It was brought from China to Europe early in the nineteenth century, but was not in general cultivation till after 1850. It is a bushy, low-growing tree, six to eight feet high, and very productive. Its fine flavour and perfume are familiar to us all in the variety known as the **tangerine.** Of still more recent introduction in the West is the Japanese **cumquat** (*Citrus japonica*), which has fruits no larger than gooseberries. They are much used for confectionery and for decorative purposes.

About 1846, we are told, a certain Captain Shaddock carried from the East to America the rather coarse and flavourless 'pomelo' (*Citrus decumana*); and from it the fruit-growers of America and the Cape have evolved, by careful selection, the delicious **grape-fruit,** which has become deservedly a favourite of recent years. There was genius in changing the name from 'shaddock' to 'grape-fruit,' for it greatly improved the flavour!

To sum up our debt to the citrous fruits: the orange, the mandarin, and the grape-fruit give us what is not only a gustatory pleasure, but, because of the vitamin content, a valuable addition to our diet; the lemon and the citron give us flavourings and, with the lime, many refreshing and health-giving drinks; the bitter orange gives us our marmalade, and its flowers yield the 'oil of neroli,' which, with 'oil of bergamot,' forms the basis of many **perfumes**; the little cumquat, the sweet lime, and the smaller oranges are preserved or candied as sweetmeats. All of them are a joy to the eye—even on the barrows on the street. Finally, when the *Citrus* tree has ceased to bear a sufficient crop it is possible to make beautiful furniture out of its hard and fine-grained wood.

DATE-PALMS.—Very dimly aware of what they do, the children gather at Easter what they call 'palm' or 'pussy-willow,' the hare's-foot-like inflorescences of the willow tree. These blossoms are conspicuous in appearing before the leaves, and are welcome to the queen

humble-bee in her early flights. Very decorative are these collections of little flowers, especially pleasing to us when the spring is tardy and even foliage is scarce. They can still be bought at Covent Garden, but we suppose the demand is now almost entirely aesthetic, whereas in the country the gathering expresses a lingering religious rite observed by many who never dream of connecting willow 'palm' with Palm Sunday. Between these two extremes there are no doubt thousands who deliberately gather the willow branches as substitutes for the leaves of palms, and in so doing are consciously commemorating Christ's last entry into Jerusalem, when the people 'took branches of palm trees and went forth to meet Him, crying Hosanna.'

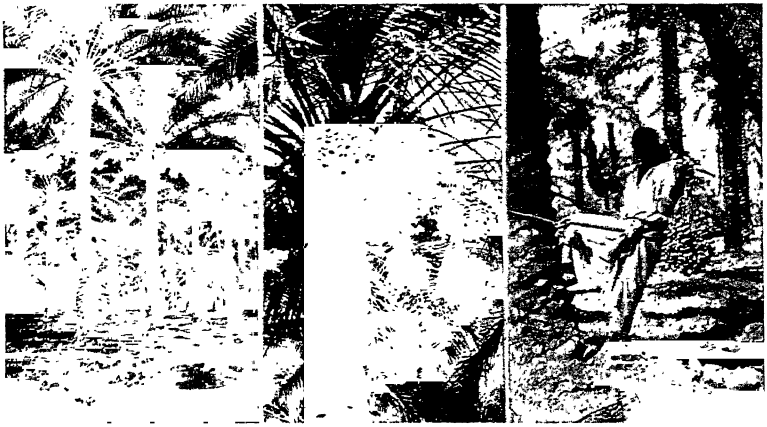
For the graceful pinnate leaves of the date-palm other foliage had to be substituted as Christianity spread northwards in Europe, and thus arose the use of willow and yew and other trees. These were blessed by the priest, as were the palms in the south, and in the same way, after being carried in procession, they were usually burned, the ashes being kept for the sprinkling of Ash Wednesday. So we link back the velvety flower-clusters of the willow to the leaves of palms, and bind the centuries in poetry. But just as it is certain that the cutting of palm branches as symbols of joy is far older than Christianity, so it is likely that the original gathering of the willow 'palms' was a seasonal custom associated with the return of spring, of which they are among the earliest floral harbingers.

One of the refreshing sights of a visit to the Riviera when the year is young is the fruiting of the date-palms. Although they are not native to Europe, being at home in North Africa and South-western Asia, they flourish well at places like Bordighera, where an admixture of sand with the heavier clay makes a suitable soil for the thirsty tree's needs. The stem rises like a graceful column, covered by the old leaf-bases, and bears as its capital, often forty feet from the ground, a beautiful head of pinnate leaves, among which, on the female trees, there hang the bunches of golden fruit. We must admit that the berries, for berries they are, remain small and acid in the Riviera, but they are beautiful none the less. What is lacking is sufficiently generous sunshine, for the date-palm must have, as the Arabs say, 'its feet in water and its head in fire.' The association of palms and wells is familiar, and the Arabs often make an artificial depression around the base of the tree, into which they pour the precious water.

The only place in Europe where the palm bears dates of marketable value is at Elche, a small town on the south-east coast of Spain, and the success here depends on the thorough irrigation. It is interesting to notice, however, that the characteristic tree of Egypt, Persia, and Arabia is now doing well in the western states of America.

The date-palm (*Phoenix dactylifera*) is a slow grower, and does not

bear fruit until it is about eight years old. It is at its best about thirty, and it may live to be a centenarian, yet without senility. We do not wonder that it has been from ancient times a symbol of victory over difficulties, even over death. For ages the Arabs have been in the habit of taking suckers from a fertile mother-tree and using them to start new trees; and yet we talk of eugenics as modern! Vigour and fertility suggest the victorious insurgence of life, and so the date-palm became a symbol of immortality, as the name 'Phoenix' suggests.



Hill Bros.

FIG. 479. DATE-PALMS (*Phoenix dactylifera*)

The Arab gets much more than fruits from his date-palms. The terminal bud cut off when young may be boiled and eaten as 'palm cabbage.' As this kills the tree it sounds like an impossibly expensive dish, but it seems that only unpromising trees are dealt with in this way. When the terminal bud of some tropical trees is cut off there is a flow of sweet sap, which is used to make **palm wine.** Boiled down, the sap yields a syrup called **jaggery.** Distilled and fermented it becomes the strong spirit called **arrack.** The wood of the tree is used for fencing and building purposes; the strong flexible leaf-stalks are plaited to make baskets, mats, and the like; the leaves form a convenient thatch. Under the trees the Arabs grow figs, grain, pulse, and vegetables, which could not be cultivated without the welcome shade. The date-palm is one of the most useful trees in the world.

Unlike most palms the date-palm has the male and female flowers on separate trees. In natural conditions the fertilizing pollen is carried by the wind from the male to the female tree, but it would not be safe

for man to leave the important pollination to chance. Therefore from very ancient times it has been the custom to cut off male inflorescences and tie them above the female inflorescences. One pollen-bearing tree is said to furnish sufficient pollen to fertilize a hundred fruit-bearing trees, and this means a very economical reduction in the number of cultivated male trees. On the other hand, it must be hard work climbing the trees and fixing on the pollinating twigs! Kerner notices a remarkable fact that the Arabs 'put aside some of the pollen from year to year, so that in the possible event of the male flowers not developing, they may ensure a crop of dates.' This is interesting since it implies great longevity on the part of the pollen grains. Experiments made with various other plants show a range of viability from two to seventy-two days. In some cases, like barley, survival seems to be a matter of hours.

Since the proper development of dates depends on the pollination of the female flowers, it is of incalculable importance to millions of people that there should be no uncertainty. Thus we can understand that it became in some peoples a religiously solemnized duty to cut the pollen-bearing twigs of the male date-palm and hang them upon the female inflorescences. As the practice goes back to remote antiquity, a new light is cast upon Palm Sunday. Is it not another instance of an ancient seasonal custom being secondarily linked to more idealistic associations?

A quaint detail may be noticed on the Riviera. Some of the trees in January showed their lower leaves bent upwards and tied tightly together at their tips, while others, in a minority, had their leaves loosely confined by a ring lower down. We were told that the former were Catholic palms, and the latter Jewish. In the former the tying at the tips prevents the light from reaching the enclosed young leaves, which therefore grow up blanched for Palm Sunday. The loose ring on the Jewish trees allows the light to enter, and the young leaves remain green in colour, though small in size and blunt in shape, the prescribed type of foliage for use in connection with the Feast of Tabernacles. Here, then, one sees two symbolical usages evolving in different directions, reinforced with new significances, yet irresistibly carrying the naturalist's thoughts back to their probable common origin in an economic, rural, and seasonal practice, so important that it became invested with religious sanctity.

COCO-NUTS.—There is a fascination in coco-nuts and our heart warms to them in the shop windows. They suggest coral islands and Aunt Sallies, monkeys and robber-crabs, sweetmeats and wine, milk and butter (or margarine at least), and other brain-stretching problems. Who need want anything who has plenty of coco-nuts?

The **coco-nut palm** is one of the commonest of tropical trees, wide-

spread among the inhabited Pacific Islands. Yet no one seems to be sure of its native land. On the whole the evidence points to the north of South America, and Humboldt thought that it looked at home in the upper valley of the Magdalena River that flows from the Colombian Andes. Eleven other species of the genus to which it —*Cocos nucifera*—belongs are undoubtedly American; and that is a strong argument.

The slender stem grows to a height of sixty feet or so, but seldom stands vertically. It bears a crown of huge feathery leaves, amongst which are hidden the inflorescences at one time, the bunches of nuts at another. The tree likes an open place flooded with sunshine, and an alkaline soil, such as the seashore often affords. As we shall explain later on, it is a companionable palm, and if we are wrecked on an oceanic island with a grove of these palms we may be sure that it is already inhabited by man, unless, of course, he has gone away. Except perhaps in Colombia, the coco-nut palm needs man as much as man needs the coco-nut.

Royal Bot. Gardens, Kew

FIG. 480. COCO-NUT PALM (*Cocos nucifera*)

The flowers of the palm form a spike-like inflorescence, but they are not very impressive. It is the fruit that is the masterpiece. What we are most familiar with is only the 'stone,' so to speak; but every one knows that the so-called nut is surrounded by a thick fibrous zone—the 'coir' of commerce—used in making the matting on which we brush our shoes. Outside that is a smooth, close-textured rind, waxed all over. The whole fruit is about a foot in length and eight or nine inches in thickness; but it usually contains a single seed. There is room for three, as indicated by the three familiar dimples at one end;

but only one develops, and the delicate embryo-plant lies to the inside of one of the three dimples. The thin seed-envelope inside the 'stone' has to the inside the white nutrient tissue, botanically called **endosperm**, and the large internal cavity is partly filled with 'milk'—a pleasant draught, they say, when it is fresh and cool.

If one cares for clear thinking one cannot call this fruit a true nut! It is not the least like a hazel-nut, for instance, where the seed rattles inside the hard wall of the fruit. But is it not more like a walnut, where, outside the wall that requires to be cracked, there is the fleshy part all-important in pickled walnuts, and outside that again a firm rind? This is the line of botanical interpretation: the coco-nut is a **stone-fruit** or drupe, like a plum—but a stone-fruit in which the outermost pellicle or **epicarp** has become rather woody; in which the juicy pulp or **mesocarp** has become fibrous; and in which the third layer or **endocarp** is thick and hard, just like the 'stone' of a peach. There can be no doubt, we think, that the coco-nut is a drupe in disguise.

To discern this is to the credit of the botanist, but we are less sure about his insistent interpretation of the coco-nut as adapted to **dispersal** across the seas. Yet this seems at first very plausible. The outside layer, firm and waxed, keeps out the water; the fibrous layer, enclosing much air, is a life-belt; the stone, which protects the delicate seed, is well suited to resist any ill effects of being battered against the rocks and coral; the large quantity of milk keeps the sprouting seed supplied with moisture until it has time to tap some layer below the salt of the shore. It is the best of all possible worlds, and the coco-nut palm grows overhanging the water so that it drops its nut right into the tide. Thus from some unknown origin the coco-nut has been carried to the West Indies and Ceylon, to Australasia and Malay, and to all the islands of the warm seas. It is a pretty story, but it is not usually true. For it seems that the coco-nut of the flotsam does not survive a long journey; it is delicate and in a hurry to sprout; if it survives the journey and the landing it is apt to rot on the shore; if the jetsam coco-nut germinates it is almost certain to be eaten by crabs; if it is lifted by an unusually high tide or wave and hurled inland on to a suitable spot, the sprouting seed will be smothered by other growths; if it becomes a tree, its nuts, falling to the ground, will fail to grow up in the bush. In fact, the fine theory has been heavily attacked, and though it would be rash to say that there is never successful dispersal of coco-nuts by marine currents, there seems almost no doubt that their successful extension over widely distant shores is wholly, or almost wholly, due to vile man! The coco-nut palm is a tender plant, requiring careful handling, and although the nut is common enough among the jetsam, it is doubtful whether it can establish itself in such conditions.

All this sounds like proving too much, for there must be some significance in the specializations of this strange fruit. The probability is that the peculiarities we have mentioned favour survival when the big nut falls off the tree in dry inland regions, where it probably lived for ages before man took it in hand. The hard parts and the springy fibre serve to break the fall; the fluid supplies moisture till the young seedling strikes root in the ground softened by the rains.

Is not the coco-nut palm more diverse in its usefulness than any other plant? The large leaves are intertwined to make thatch and floorcloth and baskets; their stalks and midribs make fences and brooms, yokes and pieces of furniture; the wood of the stem is used in building. The big bud or 'cabbage' at the top of the tree makes one of the strangest of 'vegetables,' and may be variously pickled and preserved. The inflorescence at its height is tapped for '**toddy,**' a sweet drink like the Mexican pulque; evaporation of 'toddy' yields the sugar called 'jaggery,' obtained also from other palms; and fermentation results in the heady arrack (see p. 1419), whence, if you like, strong vinegar. The 'stone' is a drinking-cup, with a pint of fluid to be drunk fresh; the quantity diminishes as the fruit becomes riper. The white flesh is eaten raw or cooked or sweetmeated; it is squeezed for fine oil, used in making soap and margarine; the dried export is called 'copra'; cattle are fattened on the refuse. The climax of the coco-nut—its supreme recognizable embodiment after death—is in the interior of a 'chocolate.' But with chocolate or cocoa (q.v.) (*Theobroma*, not very far from our lime trees or lindens) it has nothing whatever to do, being a proud palm.

THE VINE.—Vines are near relatives of Virginia creepers, and their headquarters strangely enough are in America. Some authorities separate out forty species, mostly confined to the warmer, yet not tropical, parts of the Northern Hemisphere. In Europe, however, there is only one native species, *Vitis vinifera*, which occurs both in wild and cultivated forms. The wild vine, with its well-known 'sour grapes,' frequents many somewhat moist natural woods, and climbs partly by sprawling like a bramble and partly by means of its specialized tendrils. Unlike the cultivated vine, it occurs as separate male and female plants, which differ in their foliage, the leaves of the staminate plants being more incut than those on the pistillate. The fruits are very much smaller than ordinary grapes, often about a quarter of an inch in length, and possess little juice.

The cultivated European vine has many varieties to its credit, which differ in foliage, shape of fruit, shape of seed, and in the chemical composition of their juices. The last point is interesting practically, for it affects the flavour of the grapes and the bouquet of the wine. It is also interesting theoretically, for it is a well-worked-out instance

of the chemical individuality of nearly related varieties. The same holds when we pass beyond the European species, *Vitis vinifera,* to other species.

As is usually the case with cultivated plants, the early history of the vineyard vine is hidden in obscurity; but it may be safely inferred that it began in the wild vine, and probably from several sports or

Will F. Taylor

FIG. 481. A VINEYARD ON THE CÔTE D'OR

mutants of that stock. Besides recognizing the intrinsic variability in the plant, we must also give credit to man's desire to give every new departure a chance to justify itself by going one better than its parents. Moreover, man made crosses from early times, and thus the number of different kinds increased. It was said of Democritus that he knew all the different kinds of grapes, but Virgil said that they were countless as the sand in the desert. Pliny refers to ninety-one different kinds, and Columella names fifty-eight with the remark that his list was not exhaustive. It used to be said that there were over a thousand varieties of vine in France, but in a recent monograph Professor Hegi reduces the number to three hundred and fifty. How impossible it is to ignore variability in our attempts to understand what life means,

and it must be noted that we are not dealing here with modifications directly due to differences in soil and situation, but with constitutional peculiarities that breed true. Living creatures are springs of individuality, and the vine might be called a fountain.

In thinking of this variability we must remember the antiquity of vine culture, which probably began in Asia Minor or in Egypt some 4000 years B.C. Even from Babylonian and other inscriptions a very early origin can be inferred with certainty; and there must have been many tentatives before **viticulture** was firmly established. It says much for the strength of man's gustatory impulse that it should have led to the segregating and fostering of so many different varieties of the same stock. It was a big business that Noah started when he planted his vineyard. An interesting little detail is that the experts say they can distinguish the seeds of the wild vine from those of cultivated varieties, and that the latter have been found in remains that can be securely dated at 1700–1500 B.C. It is not merely that the wild grape has usually three seeds and the cultivated grape usually two; they differ in details of shape.

To change the subject, we cannot think of vines without seeing their beautiful tendrils. Every one knows that plants climb in diverse ways. The bittersweet in the hedgerow, second cousin of the potato, is a leaner; goose-grass is a sprawler helped by the little hooks on its elongated stem; the rampageous bramble is a scrambler, also helped by prickles; the ivy clings by its numerous aërial rootlets; the hop is a twiner and so is the dodder; but highest of all are the **tendril-bearers,** among which the vine is included. It is interesting to find the same result reached along many different paths, the results being the spreading out of foliage without much expenditure in hard supporting tissue. We adhere to the Darwinian view that the climbing habit is specially fit to survive in conditions of crowded vegetation, as in the tropical forest and the hedgerow at home, where it is of advantage to get out of the dense shade. But we would add that climbers are plants constitutionally biased towards elongation of the internodes of the stem in shady places. It may be too psychological to say that they are struggling to get into the light, but perhaps we err in not being psychological enough. Perhaps they cannot help it, but climbing plants are endeavouring; and we cannot help fancying that Darwin came unconsciously near one aspect of Lamarckism in his great interest in climbing plants, on which, as we all know, he wrote a very fascinating book.

To the evolutionist it is very instructive to notice how the sensitive climbing organs which we call **tendrils** have been evolved from various quite distinct parts of the plant. For they may be transformed stem structures as in the passion flower, or transformed leaves or leaflets

as in the pumpkin and the pea, or sensitized leaf-stalks as in *Clematis* and *Tropaeolum*; and there are other origins of tendrils. This is one of the methods of **Organic Evolution** to make a new structure out of something very old, as we see in the elephant's trunk, which is just a very long nose, with a piece of upper lip added on. Nature transforms the old, so to speak, oftener than she invents the new.

What, then, is the tendril of the vine? This has been much discussed among botanists, almost as much as the tendril of the pumpkin, which has received seven different interpretations! But there seems general agreement now that the usually branched tendril of the vine represents a transformed flower-stalk. It is sensitive to contact; its growth is differentially altered when it touches a support; it makes its coils in the usual tendril fashion, and their tissue hardens. Then the portion below the point of attachment twists a little to form a spring-anchor. In some cases the tip of the tendril forces itself into a crevice of the support and enlarges into a ball, externally gelatinous and gluey. The climbing of the vine is seen to best advantage, not in the very artificial and severely pruned vineyard, but when the plant has spread luxuriantly over a house in the country. In many a greenhouse the spreading of the vine over the roof is a very beautiful sight, especially when the bunches are well formed. We remember visiting a great Breadalbane vine which we were told was the biggest in the world—which expressed, at all events, the proper local patriotism. It was as long as the distance we can throw a stone.

We are sorry to make our bow to the vine without saying something about the **grapes**, for they are aristocrats among fruits. Botanically they are berries, and a big bunch may weigh twenty pounds and more. To end on a practical note, **sultanas** are seedless varieties of the ordinary grape, and **currants** are Corinthians.

THE OLIVE.—This beautiful tree (*Olea europaea*) has long been of commercial importance, both for its wood, and for its little green or black fruits, from which a valuable **oil** is procured. It is cultivated chiefly in Mediterranean countries in the Old World, and in Florida, Chile, and other regions in the New. The tree is an accommodating one; it thrives best on limestone soil, but it will also grow where there is much schist or flint, always provided that the ground is porous enough to let the tree send its roots deep down in search of moisture. It thrives best under the rigorous pruning and high cultivation given to it, for instance, in Provence and Spain, and under these conditions it yields the largest fruits and the finest oil. But with only pruning enough to keep the branches from intertwining, and with a minimum of cultivation, it will still yield a crop—not perhaps a heavy crop, or even an annual one, yet one which is a very important item in the budget of the peasant who owns the giant trees planted by his fore-

fathers, with colossal toil, on stone-walled terraces that have endured for centuries.

The French peasant still has his own mills, and his own methods of extracting the oil. In late winter the fruits are beaten down with long sticks by the men, and are then picked up and examined by the women and children. The sound fruits are sent to the mill, where the crop belonging to each family is kept separate. The stones are removed, the fruit cut up and pressed through the mill till most of the oil, which forms about 15 per cent, has been extracted. Sheets of porous material are then laid in the oil, and it is repeatedly passed through this fabric until it is quite clear. This is the first-grade oil. A second and severer crushing yields an oil which is poorer and less clear, but still fit for consumption, while a third milling, in which kernels and all are crushed together, gives a coarse oil suitable only for soap-making and the like. Even after all this squeezing the refuse is still oily enough to be dried and used by the thrifty peasant to supplement his scanty store of fuel.

E.N.A.

FIG. 482. AN OLIVE GROVE

For commercial purposes the treatment of the olive is on a more elaborate scale, and complex machinery is used. In recent years the consumption of the fruits themselves, dried, pickled, or in confectionery, has greatly increased, and if the quality is good enough it is more profitable for the grower to dispose of his crop at once than to extract the oil. The oil industry, too, has suffered from the fact that various substitutes for olive-oil are now on the market. But it is still of considerable importance, and much research is being devoted, especially in France, to the better cultivation of the tree, the treatment

of the diseases and insect attacks to which it is subject, and the improvement of the machinery for extracting the oil.

Historically, the cultivation of the olive is of great interest. A recent authority, reporting on olive-growing in Tunis, points out that the land was desert and uninhabited in the time of Sallust (86–34 B.C.), and was the same again in the thirteenth century. But between these two periods there was a prosperous civilization with hundreds of villages. The striking difference was not due, as has often been assumed, to a change in climatic conditions, it depended on the fact that the Roman settlers in the first century realized that the light, dry soil, in which cereals would not grow, was admirably suited for the cultivation of the olive, the roots of which penetrate far down to the water in the subsoil. So they planted olives, with some figs, vines, and almonds, and a prosperous population lived a settled life. But in the seventh century the nomad Arabs began to invade the land, and cut down the trees to grow a scanty pasture for their flocks, and by the thirteenth century the devastation was complete. Numerous remains of the stone bowls and presses of the oil-mills corroborate the history.

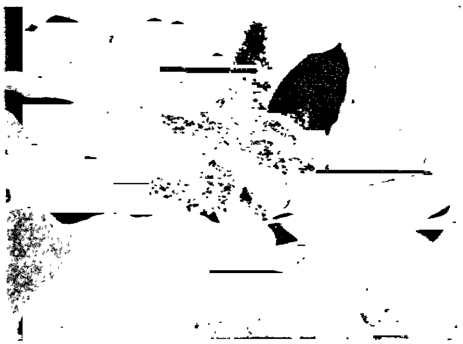


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FIG. 483. BRANCH OF MANGO (*Mangifera indica*)

THE MANGO (*Mangifera indica*).—This tree is a native of the East Indies, and a very characteristic feature of every Siamese village. It is grown in most warm countries for the sake of its large, peach-like fruits. These cannot be kept long after they are picked, so that the ripe fruit is not—or until recently was not—an article of commerce. With improved methods of storage, however, it is now being brought to the markets of Europe. Dried mangoes and sliced fruits preserved in syrup are also exported. The tree, which grows to a height of twenty to fifty feet, has rosettes of tough evergreen leaves, forming a dense, round, dark-green crown which gives a most grateful shade. The young leaves are often bright red. Drooping clusters of pale-green flowers are succeeded by clusters of oblong fruits three to six inches in length. The skin is green and tough, the stone flat.

A wild mango grows in the woods of Borneo, but its fruits are 'of the most ultra tow-and-turpentine type.' The flavour thus described is somewhat pronounced in the poorer varieties of cultivated mango,

but is not to be detected in the best, in which the fruits are large and luscious, with thin stones and soft pulp. In the case of the large-stoned, less fleshy varieties it is usual in many places to split the stone and roast the seed.

THE MANGOSTEEN (*Garcinia Mangostana*).—This is a tropical delicacy which can only be enjoyed where it is picked. The tree grows on many of the islands from the Malay Peninsula to the Philippines, but only in restricted areas on the mainland. Attempts to introduce it into the West Indies have not met with much success. The mangosteen grows wild in many of the islands, but the fruits of the wild trees are small and full of seeds. The cultivated tree is low and round-headed, with leathery evergreen leaves and waxy flowers. The fruits are as large as an average-sized orange; the purple rind encloses three to six sections of snow-white pulp, cool and refreshing, 'with a flavour resembling that of the finest nectarine, but with a dash of strawberry and pine-apple added.' It is a safe and pleasant fruit, with slightly laxative properties; the rind, on the other hand, is astringent, and a liquid infused from it is the native remedy for dysentery. Strings of dried skins are sold in the markets.

Mr. Burbidge, from whose *Garden of the Sun* we have taken the above description, tells us of many other tropical fruits that are found in the forests of Borneo. The **pine-apple** (*Ananas sativus*) grows very freely, but it is really a native of America that has been introduced into the East. The plants in the woods are not truly wild, but escapes from cultivation.

Mr. Burbidge is particularly enthusiastic over the **durian** (*Durio zibethinus*), a tree belonging to the same family as the **baobab** (*Adansonia*). The fruit, which in the forests may be no bigger than a horse-chestnut, but in cultivation may reach the size of a melon, has a leathery skin with sharp spines. The trees may attain to a height of 100 to 150 feet, with tall straight boles, and great spreading tops that dominate the forest. The clusters of large white flowers in April are a great attraction to one of the large semi-diurnal **fruit-bats** that do so much damage in tropical forests. The durian must be eaten fresh and at the exact point of ripeness. The straw-coloured pulp at its best is of the consistency of rich custard, and of a subtle and delicate flavour, which, said Alfred Russel Wallace, is 'a new sensation worth a journey to the East to experience.' But it has one drawback, which makes it advisable to enjoy it in private—it has a perfectly horrible smell!

THE BREAD-FRUIT TREE (*Artocarpus incisa*).—This tree belongs to the same order as the mulberry. It is of medium height, with large glossy leaves, and a compound fruit that may grow to the size of a melon. It is cultivated for its fruit in most tropical countries,

and is of great importance, especially in the South Sea Islands, where it is the staple food. It may be eaten raw, but is more often cooked by baking the whole fruit in hot ashes, and scooping out the very farinaceous content, which is said to resemble bread in texture, and to have a very delicate flavour. For storage the fruit may be sliced and dried; it is often ground into powder and made into biscuits. The name bread-fruit tree is given to other species in India and Australia, but the fruit of these, though much used, is greatly inferior.

'Kaffir bread' is made from the pith of species of *Encephalartos*, a cycadaceous genus peculiar to Africa.

Flavouring Substances

'When trade began between East and West, it was not the necessities of life that formed the basis . . . it was the luxuries which tempted men to brave the dangers of the sea.' And on the East we still depend for most of those spices and condiments which give savour to our food, though many of them are now cultivated in the West also.

BLACK PEPPER (*Piper nigrum*).—This is the fruit of a climbing plant which grows wild in some parts of India, Borneo, etc., and is very largely cultivated for its berries. These are bright red and grow in long clusters. Whenever they show signs of ripening they are separated from the stalk by hand-rubbing, picked clean, and dried in the sun till they become black and wrinkled. They are either used in this state, as 'peppercorns,' or ground to the familiar powder. 'White pepper' is procured by rubbing off the outer skin of the fruit, after prolonged soaking in water; it is much more pungent than the whole fruit. **Red** or **cayenne pepper** is a product of *Capsicum annuum* or an allied species belonging to the potato order (*Solanaceae*). They are shrubby plants with a woody stem, bearing the beautiful red fruits so familiar to us as 'chillies' in pickles. The fruits are also prepared as a paste for external use in medicine. The bushes are cultivated in South America.

One of the pepper plants, *Piper Betle,* supplies the leaf used in the East as part of what is called 'betel-nut.' The nut itself is the fruit of the Areca palm, and this is wrapped in a leaf of the betel-pepper, sprinkled with shell-lime, and the whole is slowly chewed. The nut, or rather the combination, has a very astringent effect, and is sometimes used medicinally as a stomach tonic, or as a cure for dysentery. The areca-nut is used in Europe in the form of powder or paste as a dentifrice.

ALLSPICE OR PIMENTO.—This is made by drying and grinding the unripe fruits of *Pimenta officinalis,* a tree belonging to the myrtle

group, which is largely cultivated in the West Indian Islands for the sake of its aromatic fruits.

NUTMEG.—The familiar nutmeg is the seed of a tree, *Myristica fragrans*, native to the Banda Islands, but now cultivated in many islands of both East and West Indies. The tree grows to a height of twenty-five feet, and has a pyramidal crown with oblong, evergreen leaves. The fruit is a large berry, golden yellow, sometimes flushed with red. When it is ripe the fruit bursts along its furrows and displays, beneath the rather tough flesh, a bright scarlet **aril** (an outgrowth of the seed-coat) very attractive to birds. It is by their agency that the seed is dispersed. For commercial purposes the seeds are picked as they ripen, and the aril, which wraps the seed round many times, is carefully unwound, pressed, dried, and sold in sheets as **mace**, which is used for flavouring purposes. The seed itself, freed from its outer covering, is the familiar nutmeg of our spice-boxes. The wrinkling on the outside is due to the pressure of the aril during its growth.

GINGER (*Zingiber officinale*).—This plant is native to tropical Asia and has been cultivated there from very early times. It is now extensively grown in the New World also, for the sake of the rhizome or underground stem, which is used in medicine, as a flavouring, or, crystallized or preserved in syrup, as a sweetmeat. The plant bears no seeds and is propagated by cuttings or suckers.

VANILLA.—This is a genus of epiphytic orchids native to the tropical forests of America. When its use as a flavouring was first discovered, it had to be sought for on the tall trees of the dense and steamy forests of Mexico and the equatorial islands, and it was therefore an exceedingly expensive commodity. But it was found that the plant would grow on the ground in a suitable climate, and it is now cultivated in plantations. The seed-pods, formed in the third year of growth, are picked before they become ripe and are dried for use. The finely flavoured pods of commerce are from the cultivated variety, *Vanilla planifolia.* The oily juice, containing the odoriferous substance **vanillin**, is also extracted.

MUSTARD.—This indispensable commodity is the ground seed, often mixed, of two different species of *Sinapis*, both European. **Curry-powder** is a compound of many spices and leaves found in India and Ceylon.

CINNAMON.—This genus of trees in the laurel order supplies us with many condiments and medicines. One of the species, *Cinnamomum zeylanicum*, occurs wild in Ceylon, but is also cultivated there. The bark, thinly peeled and rolled up, is the well-known 'cinnamon-stick,' but it may also be ground as a spice. The bark of another species, *Cinnamomum Cassia*, is sometimes used

to mix with the true cinnamon, and this tree also yields the pleasantly flavoured cassia buds. These have no connection with the cassia trees (*Leguminosae*), the leaves and pods of which form the **senna** of medicine. Another species, *Cinnamomum Camphora*, a tall tree with glossy leaves, native to India, Japan, and the Malay Islands, is the source of the finest **camphor.** The wood of the old tree, broken into chips, and boiled, or infused with steam, yields on cooling the familiar white, odorous, crystalline substance. In cultivated trees the twigs are distilled. Camphor of less good quality is also obtained in the form of little crystals from various other trees growing wild, for instance in the forest of Borneo. The natives cut down the trees, or scoop out the crystals with a hatchet, and trade in them with merchants from Singapore or Bombay.

CLOVES.—These are the young flower-buds of a tall tree (*Eugenia caryophyllata*) grown chiefly in the islands of Zanzibar and Pemba, off the coast of Africa. The original home of the tree is further west, but when it was introduced into these islands it found the warm, moist climate so well suited to its growth that Zanzibar especially has now become the chief source of the world's supply. The fruit-buds when picked are dried in the open air or under glass, and are exported, to be used in that form, or to be distilled for the active principle, **eugenol**, an oil which has many uses in perfumery and medicine.

Beverages, Narcotics and Stimulants

TEA.—The genus *Thea* includes sixteen species of evergreen shrubs and trees, of which one is the well-known decorative camellia, *Thea japonica*. But more important are the tea plants which have been cultivated in China and Japan for centuries, and more recently in Assam, Ceylon, and Java, and also to some extent in Natal. The chief species, *Thea sinensis*, with its two divisions, *Thea viridis* and *Thea Bohea*, probably arose from an Assam species, which still grows wild; and hybrids between the species are also in cultivation. Plantations are started from seed sown in parallel rows. The young plants are cut back hard for the first two or three years to make them bushy. Harvesting begins in the third year, and reaches its maximum both in quantity and quality in the eighth and ninth years. The terminal buds and young leaves at the tip of each shoot are picked early to encourage the development of the lower axillary buds; and picking takes place several times a year, the younger leaves making the more delicate teas. The picked leaves are allowed to 'wither' slowly in the sun, and during this process fermentation sets in. It continues during what is called 'rolling,' and is then increased in a moist atmosphere

until much of the tannin has been oxidized into a form which colours the tea richly but is insoluble in water.

'Green' tea, though pale in colour, has much more tannin in soluble form, for fermentation is prevented by using heat enough in the first stages to destroy the oxidizing agents.

COFFEE.—In Great Britain the consumption of tea per head of the population greatly exceeds that of coffee, while the reverse is true of the United States. The wild coffee tree (*Coffea arabica*) (see Fig. 407), an evergreen shrub growing to about fifteen feet in height, occurs chiefly in the hilly forests of Abyssinia and some other parts of Africa. It bears fragrant, white jasmine-like flowers, which develop fruits enclosing two seeds known as 'coffee beans.' The tree was first cultivated in Arabia many centuries ago, and is now grown wherever it finds the warm, somewhat hilly country it requires. Brazil is at present the chief coffee-producing country of the world, but other South American countries, Mexico, Java, and Sumatra, have also large plantations. The tree needs protection from strong or continuous wind, and from fierce sun, therefore tall, shade-giving plants are usually grown among the bushes. Hand-picking of the 'cherries,' as the fruits are called, is usual, and therefore the bushes are kept fairly low. The fruits, when ripe, are peeled from the seeds by machinery, and the 'beans,' after being skinned, dried, and polished, are ready for market.

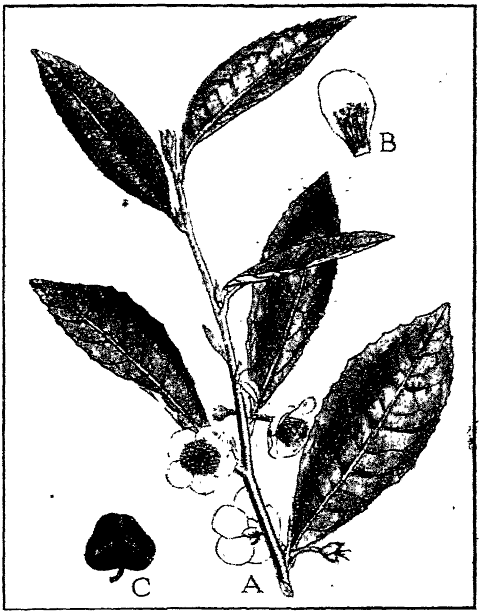

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FIG. 484. TEA PLANT (*Thea*)
A. Shoot. B. Petal. C. Fruit.

The cultivation of another species, *Coffea liberica*, has spread greatly in recent years. It grows well in moist, warm valleys where *Coffea arabica* will not thrive, and it yields a more abundant crop. But the flavour of the seeds is strong and harsh, so that they are chiefly used for mixing with milder kinds.

'Coffee-leaf disease,' a fungoid growth, difficult to guard against because the spores are carried by the wind, gives much trouble to growers in many regions.

COCOA.—The word is a corruption of 'cacao,' and its use is now mainly confined to the beverage. The cacao tree (*Theobroma Cacao*) is native in tropical America, and occurs freely along the coastal area of the Gulf of Mexico. It is now cultivated all over the world wherever the necessary conditions of warm, equable temperature and abundant moisture are found. The tree grows fifteen to thirty feet high, and has long, pointed, glossy leaves. The flowers spring from the main stem and from the thicker branches. The fruit is a thick-skinned, wrinkled pod, from seven to nine inches long, divided internally into five chambers within each of which a row of seeds is embedded in a sweetish pulp. The pods are picked by hand, or cut from the tree, and are left to ferment for several days so that the pulp may be easily removed. The seeds or 'beans' are then skinned, dried, and rolled to a fine powder, some of the oil being pressed out in the process. This oil is used to make the fat sold as cacao butter. In making **chocolate** the powder is prepared by special processes, and is mixed with various flavourings.

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FIG. 485. CACAO ('COCOA') TREE (*Theobroma Cacao*)

Cocoa owes its stimulating properties, which are comparatively slight, to **theobromine**, allied to the more active **caffeine** which is present in small quantities in tea and coffee. The same principle is present in larger quantities in the **kola-nut** (*Cola acuminata*) of West Africa. The tree is not cultivated to any great extent, but the wild nut is chewed by the natives to enable them to resist fatigue. It acts as an immediate and powerful stimulant, but its use is followed in a short time by considerable depression.

The leaves of a South American shrub, *Erythroxylum Coca*, are chewed by the natives there with even more marked stimulation and correspondingly worse after-effects. As in the case of cultivated food plants so with drugs; our knowledge of them was due to the constant experimenting of primitive peoples, and in this way new drugs are continually being added to our list. Thus it is from the shrub Erythroxylum that the important drug **cocaine** is prepared. It is of great value as a local anaesthetic, but its use is attended by so many dangers that its importation and distribution are very strictly supervised.

OPIUM.—This is another drug of great use as a narcotic, but dangerous like cocaine, since the habit of using it is easily formed and very difficult to break. It is much used by Eastern peoples both for smoking and for eating. It is the product of a species of poppy, *Papaver somniferum*, and the poisonous alkaloids are found in the **latex**—a milky fluid contained in special cells throughout the plant. The latex is of great importance to the life of the plant, for if an injury be received anywhere, the thickish fluid immediately pours out, and not only keeps off insect visitors by its poisonous properties, but hardens quickly and forms a protective covering over the wound.

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FIG. 486. OPIUM POPPY
(*Papaver somniferum*)
A. Flower. B. Leaf. C. Capsule.

The opium poppy is cultivated for its medicinal properties in many countries—British India, China, Turkey, the United States, Queensland, etc. In Britain it is sometimes grown in gardens, and in a few counties a variety of it is grown on drug farms. The poppy-heads are gathered in autumn, allowed to dry till they are brittle, and sent without further treatment to the drug factory. But in countries where the plant is cultivated on a large scale the collectors go through the fields in the early morning making cuts in the half-ripe seed-capsules, and some hours later they return and scrape off the latex, now hard

and brown. When the capsules are fully ripe they burst and liberate the seeds, but in cultivation this is not allowed to happen. For, although the seeds do not contain opium, they have considerable value as a source of oil. In some parts of Europe one sees fields of opium poppy grown for the sake of the seeds, and the oil expressed from them is used for cooking in the same way as olive-oil.

An extract from the leaves of the common wild **henbane** (*Hyoscyamus niger*) is sometimes used medicinally instead of opium, because its after-effects are less unpleasant. **Hyoscine** and **hyoscyamine**, two alkaloids derived from henbane, are powerful narcotics.

TOBACCO.—This is the most widely used, and probably, in moderation, the least harmful of all narcotics. The **nicotine**, which is its active principle, is a deadly poison, 'a large cigar containing enough to kill two men,' but most of it is destroyed in combustion. Tobacco came to us from the southern states of America, where, on the second voyage of Columbus, it was found that the use of the plant for snuffing, chewing, and smoking was 'a universal and immemorial usage, often bound up with the most significant tribal ceremonies.' The custom spread very rapidly all over the world, and seeds were carried to many countries. Sir Walter Raleigh did not introduce either the plant or the habit of smoking into Britain, but he may have done a good deal to make them popular both by his example and by his encouragement of the culture, which was started in England and Scotland in the latter half of the sixteenth century. Both the habit and the industry met with fierce opposition from the government of the day. Cromwell is said to have ordered his soldiers to ride down the young crops, and the plant was never widely grown.

The tobacco plant (*Nicotiana Tabacum*), called after Nicot, a French ambassador who carried seeds brought from Florida back to France, is an annual about six feet high, with broad leaves and pinkish flowers. The allied species, *Nicotiana affinis*, which we grow as a half-hardy annual in our gardens for the sake of its evening scent, is not unlike it. There are many varieties, and some of them can stand a considerable amount of cold, but the species is really a tropical one and yields the best results when grown in a warm country. The culture is laborious and has to be carried out with extreme care at every stage, for the flavour and quality of the leaf are greatly affected by the nature of the soil, and by the method of growing. The mineral requirements of the plant are rather strict, especially as regards potash, and artificial fertilizers have frequently to be added. After a certain number of leaves have grown, the plants are stopped and flowers are not allowed to form. The leaves are hand-picked, hung up, and slowly dried. They are then piled in heaps to undergo the requisite amount of fermentation, which differs according to the variety. Finally they

are pressed into bundles for export, the raw tobacco being subject to a lower tax than the manufactured article. There are many varieties of *Nicotiana Tabacum*, cultivated according to the different uses to which it is to be put—cigars, cigarettes, plug tobacco, or snuff. The last-named is now usually made from the midrib and leaf-stalk, dried and powdered.

Much of our tobacco comes from the southern United States, but Mexico and Brazil supply a good deal. In Cuba, where the cultivation of tobacco is only second in importance to that of sugar, the flavour is particularly fine, and the well-known Havana cigars are made from it. A different and smaller species, *Nicotiana rustica*, is grown in the East. It is known as Turkish tobacco. In France tobacco-growing is a monopoly of the Government, which buys up the whole crop. Germany grows and manufactures her own cigars; North Russia produces a coarse kind most suitable for plug tobacco, but a much finer variety can be grown in the south. Tobacco is also grown extensively in South Africa and Rhodesia.

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FIG. 487. TOBACCO PLANT (*Nicotiana Tabacum*)

The early settlers in Australia found the expense of importing their tobacco from Brazil so heavy that in 1799 they began to grow their own, and by 1880 there were many small curing factories in New South Wales and elsewhere. But because of its fastidiousness, and its exhausting effect on the soil, tobacco never became a widespread crop, and in 1924 only about 7 per cent of the tobacco used was grown in the country.

HASHISH, CHARAS, AND BHANG.—These are different forms of a narcotic and stimulating drug prepared from the resinous secretion of the hemp plant (*Cannabis sativa*). All forms of the drug, which has been known from very early times, are much used in the East, and all give rise to great mental disturbance if freely indulged in. The drug is chewed or smoked, or a highly intoxicating liquor is made

from it. The first two forms can only be dealt in under government licence, but it is impossible to enforce strict control over bhang, which is simply the mature leaves and stem picked often from wild plants, and smoked either by themselves or mixed with tobacco. The first effect of bhang-smoking is a pleasant stimulation, but this is followed by excitement, delirium, and even mania if the habit is long continued.

Drugs

Apart from stimulants and narcotics we owe to the plant world many drugs which are in constant use for the treatment of various diseases. Many of these were, like those we have described, discovered by the natives of the regions where they grow, and were introduced into other countries as the habit of travel spread. The use of many others has been handed down by tradition from the lore and legend of early times in Europe itself. The first use of these was often quite superstitious, for sometimes the remedy was not applied to the seat of disease, or even to the patient! But as people became more inquiring and less credulous, these old remedies were subjected to ever sterner sifting and testing, till finally only those which were shown to have some definite good effect were retained on the herbalist's list. But long after the advance of pharmacology as a science had brought these into the recognized armoury of medical practice, many an old woman made her living by gathering herbs and concocting 'simples' for the relief of her neighbours' ills.

It is obviously impossible for us to describe, or even to enumerate, the known and tried plant remedies of our own and other countries, but we may mention a few which are widespread in use, or of economic importance in the countries of their origin.

Of those procured from the bark of trees the most important is **quinine.** This drug, so highly valued in medicine for its tonic properties, its power of reducing temperature, and of killing germs, especially those of malaria and other intermittent fevers, came to us from the slopes of the Andes. There is no certainty as to how it was discovered, for apparently it was not an Indian remedy, but was spread throughout Europe, under the name Peruvian bark or Jesuits' bark, by the Jesuit Fathers early in the seventeenth century. The drug is an alkaloid found in the bark of several species of *Cinchona* (in the order *Rubiaceae*)—evergreen trees with glossy leaves, and pink, white, or purplish flowers. The plants vary from low bushes to trees about a hundred feet in height, according to locality, and in the warmest parts of their area they occur up to an altitude of 5,000–6,000 feet.

To get the quinine the trees were at first felled, and the bark peeled, dried, powdered, and treated with alcohol. The alkaloid is not used

in its pure state, but in the form of a soluble salt, usually sulphate or hydrochloride. Since the rest of the world had to get all its supplies of quinine from these wild trees of South America, the extravagant method of cutting down without renewing soon diminished the number and the Peruvians began to preserve them jealously. The price of the drug, too, was becoming prohibitive, so various countries sent out expeditions to see what could be done. Seed was brought to England by Sir Clements Markham and others in the middle of the nineteenth century, and was sent to the East to be grown in a suitable climate. The seed germinated successfully, but in some countries, notably Ceylon, the resulting trees deteriorated rapidly from disease. In other regions, however, they succeeded well under careful cultivation, and are now grown on a large scale. Java, where the Dutch had planted living trees, is now the chief source of the world's supply, but India and other countries grow enough for their own needs, with some over for export. The native Indian preparation includes other alkaloids, notably **quinidine,** which is said to have been used recently with good results in some cardiac affections.

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FIG. 488. EUCALYPTUS TREES

EUCALYPTUS.—The medicinal and antiseptic properties of *Eucalyptus,* which belongs to the order *Myrtaceae,* were not known till within comparatively recent times. The Eucalyptus or gum trees, of which there are about 150 species, roughly classified according to the bark as red, blue, or white gum, grow all over Australia and Tasmania. They vary in size from 'mallee scrub' to forest giants, the tallest of which, in the Victorian hills, is 300 feet high. The average height is between 100 and 150 feet. The timber is very valuable.

The red gums are very widely distributed, and the resin which exudes from the bark was early used as an astringent in dysentery, and is still an ingredient in many lozenges and preparations for relaxed throat. About the end of the eighteenth century a physician discovered that distillation of the leaves yielded an aromatic oil which could be used with good effect 'in cholicky complaints.' He sent a quart of the liquor to England, but it was not till half a century later that a serious study of the chemical properties of the oil was undertaken, and **eucalyptol** or **cineol** isolated. The species vary greatly in the amount of oil they yield. Thus in some species thirty to forty pounds of oil may be distilled from one thousand pounds weight of leaves and terminal twigs, while in others the same weight may not yield more than one pound weight of oil. The quality, too, varies from a coarse oil only fit for use in soap-making, or as a solvent, or as an external disinfectant, to the finest medicinal oil, such as that obtained from the Tasmanian blue gum (*Eucalyptus globulus*). As a disinfectant eucalyptus oil is more effective than carbolic oil, if sufficient time can be allowed, for one part of eucalyptus oil to three hundred parts of water will kill ordinary bacteria in half an hour. The vapour, too, has a disinfectant action on *moist* surfaces, and it is this fact which gives it its value, for instance in nasal catarrh. Several species of Eucalyptus have been introduced into southern Europe and have thriven well. The tree is now a striking feature in the landscape of California. A great number were planted in marshy districts in Algeria in the hope that their aroma would lessen the unhealthiness of the climate. The trees have certainly had that effect, but it is probably in great part due to the drying of the soil by their very rapid growth, which may amount to ten feet in a season.

Gums and Resins

Many trees yield gums and resins which are of great value to man for medicinal and other purposes. Technically, the difference between a gum and a resin is that the former is soluble in water but not in ether or alcohol, while the converse is true of resin. But it is not always easy to draw a hard-and-fast line, for there are gum-resins, and the latex of many plants is resinous. Most gums and resins are products of disintegration in the tree, due either to the drying up of sap or to the breaking down of tissues. 'Chewing gum' may come from any of several trees such as the pistachio or the North American sweet gum (*Liquidambar styraciflua*), but the name is now generally given to the exudation of the chicle tree (*Achras Sapota*), which is cultivated for the sake of its edible fruit, the sapodilla plum.

Gum arabic is the basis of many of the mucilages used in medicine

and the arts. It is the product of the grey wattle (*Acacia Senegal*), and is one of the chief exports from the Sudan. The shrub is not cultivated, but is allowed to grow in tangled patches with no further care than the cutting away of the thick undergrowth to give free access, and to lessen the risk of fire, which is always grave during dry winds.

Activity begins each year whenever the rains are over. The Arabs move about the thicket making slits in the bark of every tree. After a time they visit the trees again, collect all the accumulated gum, and make fresh incisions. The process is repeated several times before the next rainy season, and the accumulated gum is sent without further treatment to the nearest market town, where it is cleaned from refuse and packed for export. Other species of Acacia yield gums of different qualities, such as **gum tragacanth.**

Two species of Acacia are of great commercial importance because of the amount of tannin contained in their bark, the black wattle (*Acacia decurrens*) and the golden wattle (*Acacia pyracantha*), the first being the more valuable. Both trees are indigenous to Australia and Tasmania, and for long these countries were the only source of supply. But late in the nineteenth century the black wattle was introduced into South Africa, and now Natal produces so much of the bark that even Australia, from which the original seeds were brought, imports from there much of what she requires. The reasons for this shifting of the area of production are intelligible enough. In Australia the black wattle grew wild in the primitive forest; the population was too sparse to supply sufficient labour, and the seedling trees tended to be crowded out by more robust forest growths. In Natal, however, plantations were started and are constantly being renewed; labour is cheap and plentiful, and the peeled stems can easily be disposed of locally for pit props and fuel.

A good deal of the **tannin** used in industry comes from oak and chestnut trees, while the sumach yields a tannin that is used for the softer kinds of leather, such as morocco.

Many of the coniferous trees, especially the pines proper, exude a balsam or fluid resin, which when distilled yields turpentine and 'rosin.' The cluster pine (*Pinus Pinaster*), which thrives best near the sea, and is much grown in the south of France, yields a large proportion of the turpentine used in Europe, and the pitch pine (*Pinus Rigidus*) is the important producer in the United States. Both of these, along with many other varieties, yield pitch by a process of destructive distillation.

Kauri gum, so much valued as a copal varnish, is the product of the giant kauri pine (*Agathis australis*) of New Zealand. The tree was much valued as a timber, and great deposits of fossil gum are dug up from

the sites of ancient forests. Another very beautiful fossil resin is **amber,** which is washed up from the sea after storms, especially on the shores of the Baltic. It is really the exudate of a tree now extinct. It is of no importance as a resin, but is much valued for beach trinkets and the mouthpieces of pipes. Quite deceptive imitation amber is made from other resins, but it does not stand chemical tests which leave the genuine substance unaltered.

Oils

These also form a very important contribution of the plant world to man's resources. We have already noted many of them in discussing the plants from which they are derived, and others will be found under Cotton, Hemp, Flax, etc.

Textiles

After food in importance to mankind comes clothing, and we must therefore consider a few of the most important textiles of vegetable origin.

COTTON.—This is made from the hairs covering the seeds of some plants and shrubs of the genus *Gossypium.* These are grown in practically all parts of the world where the necessary conditions of warmth and moisture during the early stages of growth are found, but the chief cotton-producing countries are the southern United States of America, Egypt, and India. The finest quality is known as **sea-island cotton.** It has a longer staple than any other kind, the individual hairs being from one and a quarter to two inches in length. But it is a delicate plant and fastidious in its requirements, especially as to moisture, so it is grown chiefly on the seaboard of the southern states, Central America, and the islands off the coasts, while *Gossypium herbaceum*, an Old World species, is freely grown inland. The cotton plant is a perennial, but it is found most profitable to grow it as an annual. The seed is sown at some period in the early spring, according to locality, and several months of constant care are needed to bring the plant to maturity.

The flowers are yellowish or purple, the seeds enclosed within a capsule which bursts when it is ripe. The picking, which is done by hand, begins in August and goes on until frost puts an end to growth. The seeds are passed through 'gins' to separate off the floss, which is then ready to be sent in bales or bundles to the factory. There it has to be cleansed from impurities in one set of machines, and teased or carded in another, before it is ready to go to the spinning machines, in which it is rolled, twisted, and repeatedly drawn out until it is of

the proper thickness for the particular kind of material into which it is to be woven.

Great Britain imports vast quantities of cotton every year, and exports much of it again in the form of yarn and of piece goods. But much is manufactured in America, India, and Japan.

Egyptian cotton is fine in quality, and only slightly shorter in staple than sea-island cotton. India grows many varieties and manufactures piece goods, from the finest Dacca muslin to the coarsest cloth, exporting chiefly to other Eastern countries where cotton clothing is much worn. The process of **mercerizing** cotton by treating it with caustic soda, sometimes under tension, has given a new range of easily dyed, fine fabrics with a permanent silky sheen.

The great importance of the cotton plant to the world is increased by the value of the by-products of manufacture. The stems yield a fibre used in the making of paper, and the stripped seeds are squeezed to make cotton-seed oil, used in the manufacture of oleo-margarine, soap, and for other purposes. The cake that remains after the squeezing still contains about 10 per cent of oil, and forms a valuable cattle food. It is sometimes applied direct to the ground as a fertilizer. Many thousands of tons of short floss are used every year in the making of artificial silk.

The **boll-weevil** has become a very serious pest in the American cotton-fields. Originally confined to Mexico, it has spread into the southern states, and is extending its range at the rate of about fifty miles a year, so that almost the whole cotton belt is now infested. The weevil bites into the bud or flower and lays her eggs in the cavity. The grubs feed on the capsule or 'boll' and sometimes continue their meals for weeks after they are mature, so that great damage is done, even when only 2 per cent of the weevils survive the winter. Spraying with arsenic from aeroplanes is the most successful way of combating the pest, but it is estimated that the use of preventive measures and the loss of crop cost the states about £50,000,000 a year. In the Old World the chief pest of the cotton crop is the larva of a small moth, a caterpillar known as the 'pink boll-worm,' which bores its way into the capsule to feed. Rigorous measures are taken to prevent the importation of infected seed from India or Egypt into America, lest this pest too should gain a footing there.

Kapok is a soft yellowish fibre of considerable commercial importance. It is the silky hair of the seeds of the silk-cotton tree (*Eriodendron anfractuosum*), several species of which are native to America and have been introduced into the moister parts of Africa. The tree grows to an immense height; the seeds are contained within a capsule, and when this bursts the whole tree looks as if it were covered with great balls of cotton-wool. The seeds are carried for a long distance by the

wind. The so-called 'vegetable-down,' cleaned from the seeds, is used for stuffing cushions and the like, and during the war was in great demand for padding field sleeping-valises and pillows.

LINEN.—This is the oldest textile fabric in the world, and was for thousands of years the most important. The priests of olden days were permitted no other kind of material for their clothing; the wrappings of the mummies of ancient Egypt are of a linen fabric of the same kind as we still use, and traces of a flax industry have been discovered in the lake-dwellings of Switzerland. Pliny gives a description of the process of separating the fibres from the woody parts of the stalk, which shows it to be substantially the same as the 'retting' of our own day.

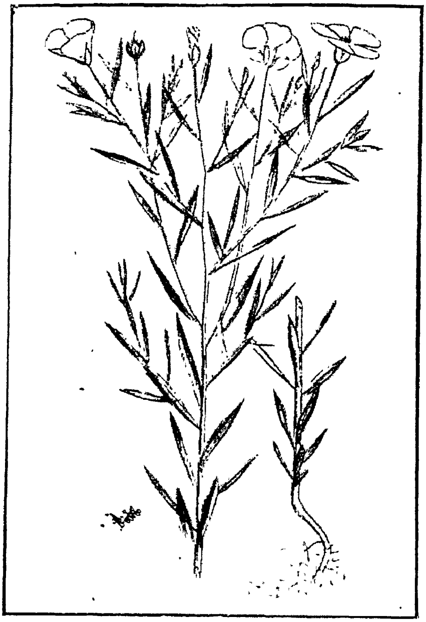

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FIG. 489. FLAX PLANT (*Linum usitatissimum*)

Until late in the eighteenth century the growing of flax and the making of linen for under-clothing were domestic industries widespread over the whole of Europe. 'Every highland glen in Scotland and every valley in Switzerland had its arable patches of flax and its hand looms for weaving the linen.' It was made in the first place for home use, but the surplus, carried to the nearest market town, formed a great part of the livelihood of many a family.

The death-blow to this fine village handicraft was given by the spread of cotton-growing, and the application to its manufacture of mechanical methods which reduced the cost of production far below the figure with which linen could compete. Thus the growing of flax soon came to be restricted to certain areas where climatic conditions were favourable, and the manufacture of linen was concentrated in particular towns. Northern Ireland, France, Belgium, and Russia are the chief flax-producing countries in Europe; and Belfast is the chief manufacturing centre for the finest qualities of linen. Flax is grown and linen manufactured in the United States, but it has never had the same importance as cotton.

The flax plant (*Linum usitatissimum*) belongs to a genus of which several species are grown in our gardens for their decorative effect. The flax of the Swiss lake-dwellings was a different species, *Linum angustifolium*. The plant is an annual which reaches a height of about three feet and has a long straight stem, branching only towards the top, and bearing blue flowers. To increase the tall, straight growth the seed is sown thickly and the plants are not thinned. The ground must be very carefully prepared, for only hand-weeding is possible after the young shoots have appeared.

The soft fibres (bast) from which linen is made are elongated bundles lying just under the epiderm, and are very closely bound up with the other elements of the stem. When yellowing begins, the plants are pulled up by hand. The first operation is to remove the seeds, and this is done by a process known as 'rippling.' Flax has been in cultivation for thousands of years, and, apart from other evidence, its great antiquity could be inferred from the fact that it has now, like the banana, lost the power of maintaining itself in a wild state without the aid of man. For the capsules do not now, as a rule, split of themselves and scatter the seed as happens in related species. As far as man is concerned, this is all to the good, for after enough seed has been set aside for next year's crop, the rest is treated to yield the very valuable **linseed oil.** In some countries flax is grown for the sake of the seeds alone. After the oil has been expressed, the residue of the seeds is still oily enough to make a very valuable cake for cattle-feeding.

After the seeds have been removed, the stalks are 'retted,' either by being laid on the grass ('dew-retting') as in Russia, or immersed in shallow tanks, and weighted to keep them under water, much in the manner described by Pliny. Close attention is necessary to see that fermentation does not go too far, and it normally takes about ten days before the fibre is ready for the various processes necessary to separate it from the rest of the stem. In America a quicker process, in which the fibre is subjected to moist heat, is generally used. When prepared, the short fibres are made into tow and lint, the longer ones graded and spun into the different thicknesses of thread suitable for making material of all kinds, from coarse canvas to dress linen, damask, fine lawn and lace.

RAMIE OR CHINESE GRASS (*Boehmeria nivea*).—This is a shrubby plant of the nettle group, used in China and Japan for making a fine, silky, and very durable fabric. Much labour is needed in the cultivation of the plant, and the preparation of the fibre, which is found on the inside of the bark. The material is used in the East for summer clothing, and is increasingly seen elsewhere in the form of tea-cloths, mats, childrens' frocks, and the like, usually decorated with

a characteristic embroidery. A naturalist-traveller, Mr. Burbidge, tells us that the women of the native tribes in the north of Borneo wear a short garment of a strong fabric made from the fibres of the 'lamba' (*Curculigo latifolia*), which grows abundantly near their houses. They are very skilful in preparing the tough fibres and weaving the cloth, which they dye with indigo. The men of the same tribe wear loin-cloths and jackets of a bark cloth made by stripping, soaking, and beating the inner bark of *Artocarpus elastica* (in the mulberry order, *Moraceae*), a tall tree nearly related to *Artocarpus incisa*, the bread-fruit tree.

HEMP.—This is the soft or bast fibre of an annual plant (*Cannabis sativa*) to which we have already referred in connection with drugs (p. 1437). The fibre is not unlike that of flax, but coarser. The plant is a native of Asia, but has long been naturalized in Europe and in the United States. When the plant is grown for fibre the seed is usually sown broadcast, and it grows to a straight stem, branching only at the top, to a height, in favourable localities, of eight to ten feet. When the plant is grown mainly for the sake of its seed, as it is in some regions, the plants are spaced out and more carefully cultivated, the result being bushy plants four or five feet high, with an abundant crop of seed. The seed is much used for bird food, and it also yields a valuable oil.

Hemp is treated much in the same way as flax, but less hand labour is required. In the United States cutting is done by a machine which lays the stalks evenly on the ground, and they are left lying until 'retting' is complete. They are then gathered up by another machine and sent to the mills in bundles. In Europe cutting is still very frequently done with a sickle.

Hemp is used for making all kinds of twine and the finer kinds of rope; the soft refuse is known as **oakum.**

The **Manila hemp** of commerce is the product of *Musa textilis*, a tree in the banana group. In Asia it is grown by the natives for their own use, and travellers tell us that every little village has its clump of Musa close by. The long fibres are found in the leaf-bases, and the bundles are separated out by hand. Beating of the fibre is practised to get a thread fine enough for weaving into clothing, but its main use is for cordage.

Sisal hemp is the fibre of one of the agaves or American aloes, an Amaryllidaceous plant now grown also in Europe. One of the species, which accumulates great quantities of sap, in preparation for the huge but infrequent inflorescence (**century plant**), is tapped by the Mexicans to make a sweet drink called *pulque*, or the liquor is fermented to make a strong spirit known as *mescal*.

JUTE.—This is the fibre of *Corchorus capsularis* and *Corchorus olitorius* (in the lime order, *Tiliaceae*), which grow in moist warm countries.

The plants are annual and are natives of Bengal, where they have been cultivated from remote times. They have been introduced into America, Egypt, and elsewhere, but nowhere have they found the conditions so well suited to their requirements as in India, and that country remains the chief source of the world's supply of the fibre. The seeds are sown from March till June, and the cutting down is done between July and October. The plants grow to a height of ten feet, and the straight stem which supplies the fibre is about the thickness of a finger. The fibre is at its best and most workable stage when the flowers are just beginning to appear.

The stalks are 'retted' in shallow tanks or in running water, in the same manner as flax, until the fibre can be beaten apart from the woody stem. It is then sorted into bundles according to quality, and afterwards pressed into great bales to be exported for manufacture. Although jute had long been grown for cordage in India, the manufacture only began to spread to other countries in the eighteenth century. In Britain the first factories were built at Dundee, and that town long remained the chief centre of the jute-manufacturing industry. It has lost much of its original importance in that respect, however, for not only do most European countries now manufacture jute fabrics, but India has erected factories of her own, especially at Calcutta, and much of the crop does not leave the country at all. Cordage, ropes of all kinds, and the coarse material called hessian are made from jute, and it also plays an important part in the manufacture of many durable mattings, floorcloths, and carpets.

Vegetable Colourings

From very early times vegetable colourings have been known, and some savage races still extract from plants the brilliant tints with which they dye their blankets. **Indigo** dye is yielded by several species of leguminous plants, especially *Indigofera tinctoria* in Asia and *Indigofera Anil* in Central America and the West Indies. In the ancient East indigo is said almost to have rivalled the imperial purple derived from *Murex*, a sea-snail related to the whelk. In Europe, before the introduction of an indigo plant, the same colour was extracted from a crucifer, *Isatis tinctoria*. This is the **woad** plant, and is presumably that used by our forefathers in ancient Britain for staining their bodies blue.

In India the indigo plant is sown just before the beginning of the rainy season. Weeding has to be carefully attended to, and the plants are cut down just before flowering begins. Their growth to this stage takes only eight to ten weeks, and it is often possible to secure a second crop in the same season. The stalks and leaves are steeped in

tanks for a day, and a yellowish liquid results. This is oxidized by beating or churning it with a paddle-like wheel until a blue precipitate is formed. But, notwithstanding the introduction of scientific methods of preparing the dye to make it 'fast,' the indigo industry has diminished in proportion to the development of the much less costly synthetic or chemical dyes.[1] **Fustic** has still some importance as an

Royal Bot. Gardens, Kew

FIG. 490. CULTIVATION OF INDIGO (*Indigofera tinctoria*)

ingredient in the compound used for dyeing wool to brown, yellowish, and orange shades. It is an extract from *Chlorophora tinctoria*, a South American and West Indian tree of the mulberry family. The heartwood of some other trees is used for browns and reds, while a North American oak, *Quercus tinctoria*, yields a yellow dye known as **quercitron.**

Logwood (*Haematoxylon campechianum*) also belongs to the *Leguminosae*. The heartwood is dark red, but the colour extracted from it varies from deep purple to pale mauve according to the mordant used in the process of preparing it. It has still considerable importance in the dyeing of black fabrics, and in the manufacture of inks. **Madder,** which used to be the sole source of the brilliant colour known as **Turkey red,** is extracted from the roots of several species of *Rubia,*

[1] Indigo itself is, indeed, now obtained mainly by synthetic processes from naphthalene.

native to Asia and southern Europe. In Europe, *Rubia tinctoria* was very extensively grown until the second half of the nineteenth century, and the amount imported into Britain in 1875 was valued at over £400,000. But experiments in making its colouring matter, **alizarin,** by chemical methods soon proved effective, and it became possible to put this substance on the market at a relatively low price. The result was that within a dozen years the value of the imports had decreased by about 95 per cent.

The **tartans** of Scotland were, up till the middle of the eighteenth century, home-dyed by the women with colours taken from heather, lichens, and broom, but the art was largely lost when the wearing of the tartans was then for a time forbidden.

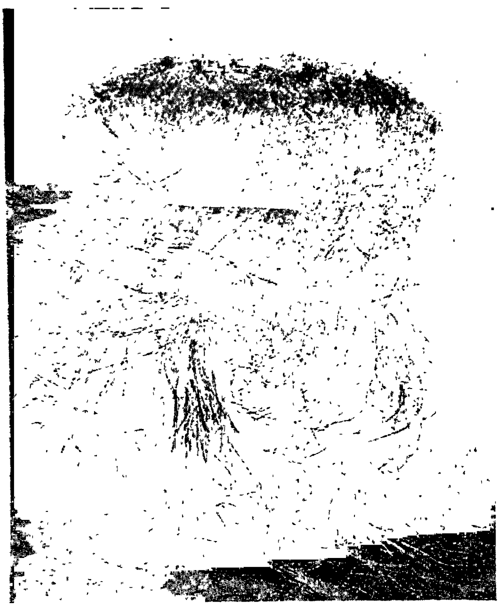
A few vegetable colourings still find a place in cookery, confectionery, and perfumery. Of these **saffron** may be taken as an example. It is the product of *Crocus sativus*, and the purple saffron or true autumn crocus is largely cultivated because of the beautiful yellow yielded by the dried stigmas. In olden days it probably came next in importance to imperial purple and indigo for dyeing cloth, but it is now little used except in confectionery. Quite distinct from saffron is safflower (*Carthamus tinctorius*), of which the leaves, dried and powdered, form the basis of some kinds of **rouge.**

INK.—We may note inks in this connection since the ordinary writing fluids have a vegetable basis. They are made from a decoction of plant **galls** (p. 305), or of any other part of the plant which is sufficiently rich in tannin. Logwood is used for copying-inks. An iron salt is added to the decoction, and the result is a bluish fluid, which turns black when oxidized by exposure to air. A sympathetic or invisible ink may be made from the plant-decoction alone, or from the latter mixed with a salt which oxidizes only when heated. Printer's ink has no vegetable basis, though its black colour is due to the element carbon.

Paper

With scarcely an exception, paper is made from the cellulose of plants, directly, or after manufacture into textiles. The oldest form of paper known is the papyrus used for manuscripts in ancient Egypt. This was made from the papyrus plant (*Cyperus Papyrus*), a tall sedge growing in many parts of northern Africa. It is still found along the edges of the streams in Nubia and elsewhere, though it has died out in Lower Egypt, where it was probably never native. The stems, whole or split, are now used for basket-making, and the rhizomes are said to be edible. For making papyrus the soft cellular pith inside the tall stem was cut into long strips and laid on a flat surface. Other strips were laid across these, and the whole was moistened with ' water

from the Nile.' When it was thoroughly soaked and soft, the mass was beaten till it cohered, and was then smoothed over with a piece of ivory or a shell. It was written upon with a sharply pointed reed. In colour it was nearly white or ivory when fresh, and it was flexible enough to be rolled up, but it was apt to become brown and brittle with time, as is shown by some of the rolls found in Egyptian tombs.



John Dickinson & Co.

FIG. 491. ESPARTO GRASS (*Stipa tenacissima*)

Paper from cellulose pulp was apparently made in China, from the paper mulberry, and from *Boehmeria nivea*, now used for the manufacture of a fine cloth. There seems also to have been a kind of paper manufactured as a by-product of the much more ancient silk industry. As in the case of silk, the secret of paper-making was divulged to the Arabs by Chinese prisoners about the fifth century A.D., and by the ninth Arab MSS. were written on paper. The manufacture spread very slowly westward through Greece and Spain, until it reached England in the sixteenth century. It is on record that the first paper-mill was founded at Stevenage 1495. Paper was at first made from flax fibre directly, but later rags and all manner of vegetable substances were used. Many plants yield cellulose quite suitable for making paper; the deciding factor is the quantity in which they can be grown, and the cheapness with which they can be pulped, for reducing the cellulose to a smooth, even pulp—commercially known as 'half-stuff'—is the first step in the manufacture of every variety of paper. For the finest kinds the pulp is pure cellulose; for the rougher kinds it is less completely separated from the other elements of the plant.

Linen and cotton rags are much used for the finest kinds of writing-paper, the first breaking-up and smoothing of the cellulose having been done in the original manufacture. But the supply of rags is not

nearly sufficient for the requirements of the mills, and other substances have to be mixed with them in most cases. Enormous quantities of esparto grass are used in Great Britain. This plant (*Stipa tenacissima*) is the 'halfa' of France, though this Arabic name covers many other species also. It is a feathery grass native to the shores of both sides of the Mediterranean. It still grows wild in many places, but, as its value increased, it was found necessary to take measures to conserve it by protection and cultivation. The fibre of this grass dissolves easily, and great consignments of it are carried to English and Scottish ports. Wood-pulp is one of the great modern sources of paper. It is made chiefly from coniferous and other softwood trees, and for a long time nearly all the needs of the industry in Europe were met by the pine forests of the Scandinavian countries. But paper-making began in America in 1700, and later, as elsewhere, it grew very rapidly owing to the colossal development of the modern newspaper. The wood-pulp used there is partly home-grown, but a vast amount is brought from the Canadian forests. Canada also manufactures paper, and her exports of the finished article and the pulp to the United States exceed in value her exports of timber for constructional purposes. A faint idea of the amount of paper required in modern life may be gained from the statement that a recent number of the *London Directory* consumed almost a thousand tons.

Wood-pulp is not sufficiently fibrous to make good paper by itself, and it is therefore usually mixed with rags or esparto. For the cheaper newspapers where durability is not aimed at, the pulp may be loaded with various minerals. Heavy wrapping-paper is made from Manila hemp, and the straw of cereals and many other plant substances are used for cardboard and mill-board of various qualities. The use of 'cartons' for food-cases and the like is a modern development which has greatly increased the use of cellulose pulp.

Papier-mâché, originally made in the East, is now manufactured in many European countries. It is made either from damp sheets of paper glued to a mould, or from pulp, usually Swedish wood-pulp, mixed with glue, and it has many uses. **Celluloid**, greatly used for ornamental boxes, combs, brush-backs, and many other purposes, is made chiefly in the United States. In this case the half-stuff is treated with acids, dissolved in camphor or other spirit, mingled with oil, and rolled into sheets, the hardness depending on the amount of oil used. Celluloid is easily worked, and may be almost transparent, but it takes colours well, as in the tortoiseshell variety. Its drawback is its great inflammability, but even that can be overcome by appropriate chemical treatment.

Cork

On both sides of the Mediterranean, especially in Spain and Portugal, and all over the slopes of the Atlas Mountains up to a height of 1,300 feet, there grows a tall oak tree (*Quercus Suber*) which has a unique importance, in that it is the chief source of the cork-supplies of the world. Many trees which grow thicker year by year form a dead cork layer on the outside of the bark, but in the cork oak this is very thick and persistent. The stem and branches are covered with much furrowed and wrinkled bark, the inner layer of which yields tannic acid. It takes from fifteen to twenty years for the first layer, which is known as virgin cork or male cork, to become thick enough for harvesting, and even then it is too rough and woody to be used for anything but tanning, roofing, window-boxes, and ornamental work generally. When the outer layer has been cut off with an axe, the layer of bark beneath it—the cork matrix—has a beautiful red colour, and on the surface of it there grows a secondary layer—the female cork—which is ready for harvesting in eight to ten years. This harvest may be repeated at intervals until the tree reaches the age of fifty years or more, the cork becoming smoother and finer after each successive stripping. It is stripped off in sheets or in continuous rings, and is then boiled in iron vessels and pressed, so that it loses some of the tannin and becomes more elastic.

FIG. 492. CORK OAK (*Quercus Suber*)
A. Shoot with male catkins. B. Acorns.

Fire is a great danger in natural cork forests, because of the thickness of the undergrowth. Harvesting is strictly regulated, and all care is taken to conserve the valuable trees.

Rubber

Rubber is prepared from the milky juice or latex of certain trees growing in tropical and sub-tropical countries. This latex is elastic and resinous, and is almost always poisonous. It is of great value to the tree, because it quickly spreads a covering that hardens in the air over any accidental wound in the stem, and, more important still, it prevents the attacks of burrowing beetles and other destructive creatures. Latex with similar properties occurs in many trees and plants in temperate countries also, but it is only in warm regions that it is produced in sufficient quantities to be worth exploiting.

Until the end of the eighteenth century a large proportion of the rubber used in industry came from Brazil, the chief producer being *Hevea brasiliensis* (see Fig. 399), one of the *Euphorbiaceae*, which yields the finest Para rubber. The latex is caused to flow by making incisions in the bark of the stem. It coagulates quickly on exposure to the air, and every few days the outer coating is peeled off, and a fresh and more copious flow occurs. Other trees were used in the Old World. *Ficus elastica*, the india-rubber tree, of which small specimens are often grown in pots as decorative plants, was the commonest rubber-producing tree in India, but it is of little importance now. The tree begins life as an epiphyte, but soon sends out roots from its base and adventitious roots from the branches, and these penetrate the ground, so that the Ficus becomes quite independent of its host, if indeed it does not kill it.

In Central America, Central Africa, and the Belgian Congo rubber is yielded by *Castilloa elastica* and several other trees which grow in the hot moist recesses of the jungle. In Africa it was gathered, often under compulsion to pay taxes, by natives who had to penetrate many miles into the jungle, and often cut down the trees to make sure of the necessary quantity. They collected it by the simple method of smearing the sticky fluid on their bodies and leaving it to dry—a method also sometimes employed by the opium-gatherers in the East. A less elastic variety of rubber, known as gutta-percha, is yielded by various trees of the *Sapotaceae* family—a family which also includes the chicle or ' chewing-gum ' tree.

As the importance of rubber to modern life increased, it became apparent that the old haphazard methods of procuring it would soon exhaust the supply, and rubber-planting began. In Ceylon and Malaya great plantations were made, *Hevea brasiliensis* being the tree used. The trees do not yield a sufficient amount of latex in their young stages, and tapping spoils their growth, so that no return can be looked for earlier than the eighth year. In Ceylon an experimental station has

been established, and scientific workers are continually engaged on the many problems connected with the welfare of the trees.

The use of rubber in waterproofing fabric by spreading layer after layer upon the material was discovered about the end of the seventeenth century. In 1823 Charles Macintosh patented the kind of garment still known to us by his name. Later came the process of impregnating the fabric itself with a solution of rubber, and this enormously increased its range of usefulness, since it made it available for tyres, for the insulating material so much used in the electrical industry, as well as for many of our minor comforts, such as goloshes, tobacco-pouches, and hot-water bottles.

Later still came the process of vulcanizing the rubber by boiling it with sulphur, the vulcanite being hard in proportion to the amount of sulphur used. Hard vulcanite is used for the making of dental plates, for parts of medical and surgical instruments, and for combs, boxes, and small objects almost without number. Synthetic rubber can be successfully manufactured, but as yet only at too high a cost to make it a substitute for the natural product.

Timber

We have already noted many of the products of the trees of the forest that are almost indispensable to man: fruits and nuts, gums and resins, tar, tannin, turpentine, oils, alcohol, and many others. It remains to consider the uses of the wood or timber, and the trees best adapted to these uses. There are so many uses and so many trees, that it is possible to select for each purpose according to strength, hardness, elasticity, and the 'graining' due to the disposition of the various elements of the wood, or, in the case of coniferous trees, to the alteration of porous and dense layers.

The conserving of timber-supplies is a serious problem in most countries, for, before the possibility of scarcity was realized, there was an improvident cutting of large trees without replanting, and though now reafforestation is everywhere beginning, the more valuable timber trees take so long to mature that new sources of supply have to be looked for. This is particularly true of Great Britain, which has not sufficient area to be self-supporting in this respect, even apart from the fact that there was an almost wholesale felling of trees during the European War. An advisory committee is constantly at work investigating the possibilities of the timbers in all parts of the empire.

Timber trees are divided according to their texture into softwoods and hardwoods, corresponding roughly to the botanical divisions, Gymnosperms, cone-bearing, and Angiosperms, flowering trees. It is among the first group that the most valuable timbers for building and

general constructional purposes are found. This is due partly to their special properties, partly to the fact that they are easily grown and easily worked, and can be procured in large quantities. *Pinus sylvestris*, the Scots pine, which grows on high situations all over Europe, has long been the most generally used timber in Britain for building purposes. Large quantities are imported under the name of Baltic redwood, and when cut it is known as yellow deal. For internal building it is often replaced by an American pine, *Pinus strobus*, imported from the eastern United States. The Douglas fir, grown and used extensively in the western United States and all over Canada, is in increasing demand in Europe also because of its great strength, durability, and lightness. It can be got in large dimensions, and is therefore well suited for railway carriages, sleepers, masts, flooring, and the like. The Sitka spruce is also tough and elastic, and the finest qualities are used for aeroplane work.

Of hardwoods by far the most important timber is the **oak,** which holds the palm for durability and for resistance to changes of weather. Ships were built of it before the days of iron vessels, and it is still used for many purposes in shipbuilding. '**Greenheart**' from British Columbia is 'probably unrivalled' for wharves and marine construction generally, because of its resistance to the attacks of boring marine organisms. **Teak**, from an Indian tree, is used for the same purposes as oak, and is the best substitute for it, while elm, beech, ash, and birch all have their special applications.

Of ornamental timbers for cabinet-making **mahogany** takes first place. It is durable, more easily worked than oak, and takes a high polish. It is really the wood of *Swietenia Mahogoni* from Honduras, but quite a number of other trees yield a very similar timber, and commercially they are grouped under the same name. Various **walnut** trees are also used for furniture. **Rosewood** (*Dahlbergia*), of which there are many species in warm countries, is used for fine furniture, and is especially suited for piano-cases. The same is true of **ebony,** from many ebonaceous trees which are black because of a gum-resin in the heartwood.

CHAPTER VI

MAN AND BIOLOGY

The hand of Man upon the earth—Civilized society and Wild Nature—The curve of life—Control of life—Mankind in the future—What Biology means to Man—Illustrations of Man's achievements.

The Hand of Man upon the Earth

There are three worlds in which we live. First, there is the **Sociosphere,** the Kingdom of Man, still very much in the making, and always a good deal in the air, for it is in great part a world of ideas, feelings, purposes, which we try to translate into the actual deeds and things, movements and life. It is a great world of institutions, organizations, cities, cloisters, churches, schools, enterprises, sciences, literature, art, permanent products, inventions—and, as Walt Whitman said of 'the World below the Brine,' there are 'wars, pursuits, tribes' in its depths. Its best title is the Kingdom of Man, a title with a challenge and a promise, and with a suggestion, perhaps, of a hope that it may some day become more like a Kingdom of God.

If the Kingdom of Man is compared to a sphere, and called the Sociosphere, we may continue the figure of speech and say that it is enveloped in another, the **Biosphere,** the Realm of Organisms. For man is surrounded by, and, after all, is dependent on, the world of living creatures, plants and animals—Animate Nature, as we say. Man's relations with the plants and animals of the world are many and varied, but there is no doubt that—unless synthetic chemistry makes some extraordinary stride—we must remain fundamentally dependent on plants for food, and in the long run for breath. We lunch on the flesh that not long ago was grass, and the oxygen in the air is mainly a by-product of the photosynthesis effected by green plants.

On the vantage-ground gained by plants the animals have advanced and man stands erect. Until the Age of Electricity began, much of the intensest human industry was quite unthinkable apart from the remains of the flowerless forests of the Carboniferous Age.

Man is not only dependent on the biosphere, he continually tends to take part of it into his own kingdom. He domesticates animals and cultivates plants; he multiplies fishes and sows the prairies; he

makes the dog a partner and the tree a ship. He takes part of the biosphere into the sociosphere.

But to our diagram of a human sphere encircled by a plant-and-animal sphere we must, of course, add the all-embracing and all-penetrating **Cosmosphere,** which includes the entire physical universe, but, for *practical* purposes, means the sphere of chemical and physical activities that have to do with us. It is the domain of things.

It includes the solid earth on which we tread, her dead daughter, or dwarf sister, the moon, and the sun from which we receive all our power. It includes the planets, the stars, and the nebulae, but perhaps we do not owe much to them except science, and this also, that long ago our whole system of worlds arose from a vast nebular universe. The cosmosphere includes all forms of matter, from dew-drops to diamonds, and all forms of energy, from cosmic rays to light and heat; it includes earth and air, water and fire, to which more learned names might be given. The fundamentals are electrons, protons, neutrons, etc., and electro-magnetic radiations or ether-waves. We are not forgetting mind—but some of the philosophers tell us that mind includes all.

Now the question that we wish to ask is this: How have man's fingers moulded the earth? Earthworms make mould; lichens crumble the rocks; corals build breakwaters; beavers cut canals; seaweeds break the force of the waves; bog-mosses are reservoirs which keep the springs welling and the streams flowing when there is no rain: the hand of life is upon the earth. But we wish to focus attention on the operations of man, a subject admirably dealt with by Dr. R. L. Sherlock in his book, *Man as a Geological Agent*. What has man done to break down his home, to conserve it, to undermine it, to encumber it, to beautify it, or to make it ugly?

When the burrows made by water-voles cause the bank of a stream to fall in, with the result that much good soil is swept down to the sea, the geologist calls this denudation. As a matter of fact, the hills are always flowing down into the sea; and man is one of the denuders. The earth itself makes corries, man makes quarries; the earth washes out rivers, man digs canals; the glacier gouges out a glen, man excavates a railway cutting; the frost's fingers break the rocks in pieces, man's mills grind the granite into chips or the pebbles into powder at Johannesburg, to set free the precious particles of gold, and much life-destroying dust (when we were there) at the same time.

Dr. Sherlock calculates that man has excavated Great Britain to an amount that would correspond to a general lowering of the surface by towards six inches in about two thousand years—and mostly in the last century. But the rate of surface planing effected by rain and frost and the like in Britain is estimated by Geikie at 2·72 inches

in two thousand years, or less than half that due to man during the same period.

Coral-polyps filch salts from the sea and build up islands and breakwaters, such as the Great Barrier Reef, which is about a thousand miles long. Does man ever add to the dry land? Perhaps he is a rock-maker when he hardens clay into bricks and binds the soft sand with lime into mortar, and builds therewith his skyscrapers and great cities. As Dr. Sherlock says, such accumulations as embankments, colliery dumps, or masses of brickwork must be geologically regarded as 'man-made rocks.'

Much more important, however, than piling up accumulations, short-lived in most cases, though occasionally defiant like the Pyramids, is man's protective agency in lessening the wear and tear of the coast-line. It is a rather striking fact that during the thirty-five years ended 1911 the British Isles increased in area by 41,362 acres. But it is to be gratefully remembered that Britain is at present in a state of relative terrestrial quiescence, for a slight land subsidence would at once undo all that man has recently done to conserve.

Very noteworthy are man's efforts towards inland conservation by planting forests, by strengthening the banks of rivers, by anticipating floods, by economic drainage, and so forth. What our forefathers lost to the country by deforestation, we are seeking to regain by planting trees or by prohibiting the removal of shingle from the seashore.

Many other examples might be given of man's direct influence on the cosmosphere. Let us take one more. Man's production of carbon dioxide by burning fuel has been increasing at a prodigious rate. What if its continued increase leads to an overloading of the atmosphere with this poisonous gas—an overloading which the vegetation, hungry as it is for the carbon dioxide, will be unable to lighten! What a hurry there would then be to plant trees! [1]

Civilized Society and Wild Nature

By 'Wild Nature' we mean the fauna and flora in countries or conditions where they have not been appreciably affected by man's interference. Thus there is not very much 'Wild Life' in Great Britain, for even the great moorland expanses often bear the marks of deforestation, and many of the wild animals of bygone days have been hunted and trapped out of existence. One likes to see the sheep on the hills, and the sheaves in the harvest-fields, but flocks and sheaves are very unnatural. No doubt the taming of Wild Nature

[1] It must, however, be remembered that, since carbon dioxide is soluble in water, the sea acts as a regulator of the proportion of this gas in the air.

is an outcome of human evolution, and has amenities of its own; but for our present purpose we wish to think of the state of affairs that obtains in places where man has not yet entered into his kingdom, save as scientific explorer. And we wish to contrast this Wild Nature not with primitive and simple societary forms in the past and present, but with the complex civilized society of which we are members for better and for worse. How are they contrasted, and why is the contrast not altogether to our credit?

There is much that is encouraging in the progress of preventive medicine and sanitation, but when we look around in civilized society we see an appalling outcrop of disease. This, biologically considered, is of three great kinds: (*a*) constitutional, (*b*) occupational or habitudinal, and (*c*) parasitic and microbic. Constitutional diseases, such as some kinds of diabetes and epilepsy, appear to be due to inborn defects or disturbances, and they are practically unknown in Wild Nature, where, if they show face at all, they are nipped in the bud. Occupational or habitudinal diseases, such as are illustrated by lead-poisoning and extreme obesity, are practically unknown in Wild Nature, though common enough among domestic animals. In Wild Nature there is stern selection for health, and a sharp intolerance of bad habits. As to microbic diseases, such as tuberculosis and malaria, which are so common in mankind, one must admit the possibility of epidemics in Wild Nature, but there is not much proof of their occurrence except when man has intruded. It is possible that the horses which used to be so abundant in America were exterminated by some *Trypanosoma*, but this is only a speculation. It is possible that some microbic disease hastened the puzzingly rapid disappearance of the passenger pigeon, but this has not been proved. We venture to say that microbic diseases are very unusual in Wild Nature.

The critic may remind us of microbic and fungoid disease in salmon, of diphtheria among wood-pigeons, of the *pébrine* that is so fatal to silkworms, of ' foul brood ' among hive-bees, and so on through a long list; but it will be found that in most cases the conditions are not those of Wild Nature, but of human interference. There is a well-known bacterial disease among sand-hoppers—well known because so unusual —but here again we must make sure that pollution by sewage or the like is not the cause.

If the critic refers to the *Trypanosoma* that occurs abundantly in antelopes and other wild animals in Africa—a trypanosome which is believed by many to be the same as that which causes sleeping sickness in man and nagana in domestic stock, the answer is that these internal beasts of prey, as they may be called, seem to be almost harmless to their wild hosts. The exception proves the rule.

Similarly in regard to parasites, which are certainly common in

Wild Nature, the usual state of affairs is that a give-and-take compromise is arrived at between the host and the parasite. Mutual adjustments bring about a *modus vivendi*, and in many cases the presence of numerous parasites is immaterial, unless some other factor, such as scarcity of food, enfeebles the vigour of the host. When parasites rapidly destroy an animal this is usually due to their getting into an entirely novel host that has no natural defences in the way of 'anti-bodies' and so forth. We admit, however, that troubles due to parasites occur in Wild Nature apart from human interference; we maintain, on the other hand, that there is only a very rare occurrence of constitutional, habitudinal, or microbic disease.

The reasons for this contrast between civilized society and Wild Nature are briefly these: (1) that social conditions are still too often inadequate, or even bad; (2) that we also shield individuals who would be rapidly eliminated by Natural Selection; (3) that the progress of curative medicine makes much cobbling practicable, and enables man to evade natural penalties; and (4) that our health-conscience is still very dull.

A second contrast between civilized society and Wild Nature is that the latter abounds in exuberant vigour, while the former shows an appalling diffusion of gloomy sub-health. One must distinguish, obviously, between the absence of disease—not that this would be a small thing—and positive health. Why is there so much depressed vitality in our midst? Partly because man is so easily led away from health by ambitions so strong that they force him to ignore or disregard the associated deterioration of physical vigour. Partly because of temporarily effective stimulants and fatigue-disguisers. Partly because there is in mankind so little of the resting instinct which is strong and imperative in many wild animals.

No naturalist, however optimistic, would assert that Wild Nature is without trace of anything corresponding to 'the unlit lamp and the ungirt loin.' For, quite apart from parasitism, there are many instances of creatures that take things easily, drifting rather than swimming in the tide of life. Yet even among those animals that show implicit acceptance of such mottoes as 'Ca' canny' and 'Safety first' there is very little indication of depressed health. The chief reason for this is to be found (*a*) in the direct competition between organisms, and (*b*) in the struggle between organisms and their environment; for this twofold endeavour is ever insistent on physical fitness.

A third, often painful, contrast between civilized society and Wild Nature is that the former shows so much pathology of sex, and the latter so little. There are some ugly sex facts even among wild animals, but they are not common, and on the whole one must say that if the animal never rises so high as man it rarely falls so far. But

why is it that ' sex ' is so often pathological in man, so rarely ugly in, say, birds? Part of the answer is that social and ethical considerations lead to repressions which bring dangers and troubles, but another part of the answer is that sex-selection in birds is largely determined by vigour, agility, and the ecstasy of health. There is too little of this kind of selection in mankind.

But the biggest fact that lies behind these contrasts is the difference between a human society and a herd. In man's case so much depends on the extra-organismal social heritage, which is at once a blessing and a curse. The social heritage of customs and traditions, manners and morals, institutions and enregistered ideals, is indispensable to us; yet it allows of the survival of organisms with a bad natural inheritance, and it brings to us from the past, and from the industrial palaeotechnic age in particular, an objective and a subjective net in which we sometimes seem to be struggling in vain. In a society the force of habits is raised to a higher power, and for evil as well as good. In a society there are engendered ambitions and appetites (plus and minus again) whose intensity enables them to dominate over our vague ' instincts ' of physical health. Much of our disharmony is due to the rapidity of our social evolution, upwards and downwards, to which as organisms we have not had time to adjust ourselves, whether in acquiescence or in rebellion. It comes to this, that biological ideals, such as that of better health, cannot be realized without the aid of corresponding social ameliorations—if not indeed transformations, in important respects.

The Curve of Life

Our life begins and ends in sleep. There is the ante-natal sleep and there is often an ante-mortem sleep. During the ante-natal sleep, when all our members in continuance are fashioned, there should be quietness, without stimulants or over-excitements, for the unborn child lives in the most intimate partnership with its mother; and it is during this period that all the nine thousand million cells of the cerebral cortex are developed, there being after birth no increase in their number. The subsequent history of the brain is concerned with growth and the establishment of more and more complex linkages among the multitudinous units.

What an unprepossessing bundle of fragilities is the new-born babe, but it is itself and no other—in some measure a novelty or variation, a new pattern of old hereditary strands. It is comparable to a group of buds and, as Walt Whitman well said, these are ' to be unfolded on the old terms.' That is to say, they must have the closest possible approximations to sunshine and fresh air, to the wind and the rain,

and to other primeval influences. Without these, some of the buds may remain unopened.

The greatest differences between a human brain and that of a gorilla are in the three areas that have to do with precise muscular movements, with speech and with the understanding of it; and it is interesting to know that these three parts of the brain are the last to be completed in the unborn child.

We hold it to be the limit of infancy when the child begins to speak —to express a little judgment of its own in socially significant sounds which it has imitated. Herein it crosses, along this line, the human frontier. Its often reiterated precious 'words' during the later months of infancy do not sound the note of language. It is also during the period of 'tender years' that the child serves its apprenticeship to movement and manipulation; and if restlessness and experimenting, so often misunderstood, are not in evidence at this time, the outlook is not too promising. This is the period for all sorts of 'liberating stimuli,' such as changes of scene and simple toys—the more unsophisticated the better, but if possible not ugly.

The childhood arc on the curve of life includes the play period and the beginning of schooling. The biological importance of play is fourfold: it affords a safety-valve for overflowing spirits; it is an opportunity for testing novelties or idiosyncrasies before responsibility is serious; it is an unconscious apprenticeship to the work of life; and it is a discipline in 'give-and-take' and self-subordination.

Schooling includes an attempt to shorten the individual's recapitulation of racial history, and apprenticeship in the use of tools such as the pen, a guidance in the furnishing of the mind, an opening of doors for intellectual and emotional adventure and enjoyment, and eventually a discipline in brain-stretching. One of the most outstanding features of childhood, outside both play and schooling, is impressionability. As Walt Whitman says:

There was a child went forth every day, and what that child saw became part of him for a day, or for a year, or for stretching cycles of years.

Here, as ever, we see the mingling of risk and enrichment.

This arc on the curve of life is full of storm and trouble to many, yet a joyous heyday to others. It is a time of new differentiations and integrations, with correlated 'growing pains'; and therefore there is need for plenty of rest. Yet it is pre-eminently a time for vigorous exercise and adventure, and even for learning to endure hardness.

The cup of life should be full; the test is to hold it with a steady hand. The calls of sex-impulses are insistent, and the secret not only of safety but of nobility is in reviving the old ideals of chivalry.

Both sexes must hitch their wagon to a star. The natural climax of adolescence is love-making, and the biological secret here, as we may learn from many of the birds, is in the subtlety of the attraction. One of the great lessons of Organic Evolution is that physical fondness is sublimated in lasting aesthetic and emotional attraction, and that again in a loving partnership in practical endeavour.

The commonplace of experience is that a successful matrimonial voyage requires three sails—a mutual physical attraction whose roots cannot be unearthed, an aesthetic and emotional linkage which outlives fondness, and an intellectual sympathy which reaches its climax in the synergy of some high-pitched endeavour—not least in making a beautiful home and rearing a healthy family.

A bit after fifty for men, earlier for women, when the sex-impulses normally wane, there is a dangerous arc on the trajectory of life, especially if the need for hard work and fitness becomes less urgent. The safeguard is to have lasting hobbies and enthusiasms, and to make new departures. The danger is in artificially fanning the normally smouldering fires.

The arc of senescence is not known to all, for the end may come before the span is normally completed. The 'accursed shears' may take the form of accident, exposure, overstrain, some virulent microbe, or some malignant growth—a mystery still. Normally, however, there are the years of ageing, of declining powers, of slower reaction, of less acute senses, of diminished vigour. He or she makes a success of a strenuous life whose senescence never becomes senility—for senility spells disintegration.

The recipe for pleasant senescence is to avoid in time the accumulation of physiological or psychological bad debts, to have keen interests in reserve, and to join the ranks of the old and bold, so that one may be young when one dies.

Man's endeavour should be to make the most and the best of each successive arc on the curve of life.

Control of Life

Many people get so much varied exercise in the discharge of their daily duties that they have not much need for dumb-bells or similar adjuncts to keeping fit. Busy men and women are apt to be too hurried in the morning and too tired in the evening to be very enthusiastic over physical training or breathing exercises. Moreover, many oldish people must admit, if they are frank with themselves, that they were educated to acquiesce in a somewhat humdrum standard of health. As the years pass, they become more and more content to jog along.

For most of us who read this book there is a fine opportunity to attain to a high level of positive health. For the sake of efficiency, as well as of health and happiness, we should take lessons in the art of life—even in such elementary things as walking well, sitting well, breathing well, resting well, sleeping well, and even dining well.

We are too apt to jog along with our bodies, refraining from gymnastics; but this is still more true in regard to our minds. Some people have, of course, to do a certain amount of precise thinking every day, but one becomes astonishingly successful in evading this. We fill up the few chinks of our full day with desultory reading or pastimes like bridge, almost afraid lest we be left in solitariness and forced to think.

How few people ever give their minds an airing! How rare is an enthusiasm for brain-stretching! What we cultivate is mental inertia; the thought of mental gymnastics sends a shudder through our being. But as this easy-goingness does not make either for efficiency or for the enjoyment of life, we wake up at intervals—more and more widely spaced—and seek advice on the subject of mental exercises.

We wish to recommend a wholesome and wise guide: Dr. R. H. Thouless's *Control of the Mind*, 1927.

THE PRACTICE OF AUTO-SUGGESTION.—When a man sits down beside his collapsed motor and says, 'The car is going better and better,' we regard him as a fool; but when our partner on the golf-course asseverates before putting that he sees 'the line to the hole,' we know to our cost that he is a wise man.

Auto-suggestion is a powerful factor, but it has its limits and its dangers. It will give us confidence when we are nervous, but it will not conceal lack of preparation for our duty. It may make us unaware of our toothache, but it will not remove the hotbed of bacteria that cause the pain. It should be employed in regard to processes that are normally automatic, like falling asleep or forgetting irritating trivialities, but it should never be used even to supplement processes that are normally under willed control.

If we wish to catch our morning train we must jump out of bed; we must on no account repeat to ourselves the formula: 'I am just about to rise.' But what the successful putter does is quite legitimate, for he is inspiring himself with steadying confidence by recalling, sometimes over-audibly, that this is just the sort of putt that he has holed hundreds of times.

When we do the same thing over and over again it becomes easier, till we may become so habituated that we do not need to attend to the process after it has got under way. The advantage of this habit-forming is that it sets us free to do other things—a decided advantage

if the habit is a good one. Unfortunately, however, the habit is often bad. Thus the control of the mind demands two opposite processes: (*a*) forming good habits, such as stretching our brain a little every day, and (*b*) breaking bad habits, such as allowing prejudices for or against particular people to colour our judgments.

SHOWING OUR FEELINGS.—Emotion is the great driving force to action, but it may drive us to wild folly. The steam may burst the boiler. Hence the importance of thinking about the control of the emotions—a particularly difficult kind of control since the emotions are very closely interlinked with the bodily secretion of powerful hormones. The angry man's body may be spoiling for a fight though his mind is that of a pacifist.

Two very simple counsels may be noted. We should discourage the habit of showing emotion unnecessarily, of cultivating anger over trivialities, of habituating ourselves to becoming excited over crumpled rose leaves. No one wishes young people to cultivate a stolid nonchalance in face of earthquakes, but it is a bad habit to allow a nervous habit of being startled to confuse a well-reasoned serenity. The other counsel is to encourage the habit of thinking quietly over, and even describing to ourselves, the event that so perturbed us that we were able neither to hold nor bind in our emotion. And another aspect of this is to have some great ideals and noble feelings in reserve for emergencies.

CONCENTRATION.—The Hatha-Yogis of India practise concentration so severely that they say they can stop the beating of their heart. This is a very useless and dangerous thing to do, but it illustrates the possibility of riveting the mind on a particular subject. Concentration greatly increases the rapidity with which we get through our work and the penetrating power of our understanding; it sharpens our subsequent memory; and it greatly lessens the minor worries of life. We once knew a thinker of distinction who wrote a remarkable book on the corner of the mantelpiece as he stood waiting for family meals, and it was not a book of casual remarks.

How admirably concentrated children often are over plays of their own! The moral is to cultivate concentration on things which naturally rivet our attention, so that it becomes a habit extending to tasks that have to be discharged whether we like them or not.

Mankind in the Future

It was said of old time that man stands by himself and apart from the rest of creation in his power and habit of 'looking both forwards and backwards.' Some of the higher animals take part in their own evolution, e.g. in choosing their environment, or in hurling themselves against limitations and difficulties, but they do not think out a policy.

They obey the 'urge for more' which life always implies; but they have no ideals. Their behaviour does not rise to the level of conduct. They have a fugitive memory, but they do not think of their past history. In these respects man stands apart, looking forwards and backwards.

Thus it is a duty, not a pastime, to think of the future, and of the further evolution, either up or down, which the future is sure to bring, unless some unforeseen doom befalls our race. The application of science to life demands prediction. We must seek to chart the seas into which we send our vessels; and according to the accuracy of our charting will be our civilization's chance of avoiding the disasters that have meant shipwreck to so many that have gone before. What in a general way has the future in store for us, if there is continuity in evolution? Are there progressive changes that may be reasonably looked for and worked for? Are there retrogressive changes that must be expected along certain lines unless we mend our ways? In the present generation we have begun to ask these questions with a new insistence, having realized that 'the lap of the gods' is woven out of the thews and sinews of mankind.

It is indeed possible that a direct scientific endeavour to secure human progress may in some measure defeat itself, just as the direct pursuit of health may land a man in valetudinarianism; but even this tax on directness may be insured against. As Professor J. B. S. Haldane says in his *Causes of Evolution* (1932), there is a new hope in the fact that man has begun (during the passing generation) to gather knowledge towards taking charge of his own evolution. 'There is at least a hope that in the next few thousand years the speed of evolution may be vastly increased, and its methods made less brutal.' In any case, the more all-round our prophecy, the less will be the risk of over-directness and one-sidedness; and only mole-eyed men and women can fail to appreciate the wisdom of the old advice to seek first the Kingdom of God. For while biological counsel is, to our thinking, fundamental, it requires to be complemented by the exhortation to pursue the supreme values of truth, beauty, and goodness.

(1) **MORE WEALTH.**—There is every likelihood that the future will bring man more true wealth, meaning by that a command of natural resources and energies, and a utilization of these towards an amelioration of life. The supply of coal will decrease, and also its wasteful usage, but electrical energy will increase (e.g. from wind and wave and waterfall), and likewise its more economical neotechnics. If the increased wealth, i.e. command of energies, is associated with more reasonableness in its distribution, which is obviously an entirely different problem, then there will be a general raising of the standard of life's amenities. Thus there will be more gardens. Our reason for regarding absolute increase in wealth as a certainty of the future is

obviously to be found in the fact that the past applications of science have been for the most part in the direction of greater control over natural resources.

(2) **EARTHLY PARADISES.**—With increase of wealth will come an increase in more or less permanent treasures, such as fine gardens, beautiful houses, and other achievements of the artists. People will continue to buy 'securities' and the like with their savings, for they will not soon lose the desire to be free from anxiety as regards themselves and their children, but they will insist on realizing their wealth in the here-and-now. They will insist on gaining possession of the beautiful, the restful, the changeful, the enlivening, and other real assets that make men rich indeed.

(3) **CONQUEST OF DISEASE.**—It is practically certain that the future will see a conquest of most of the microbic and parasitic diseases. This conquest of disease is already a conspicuous feature of modern times, and it is bound to continue, if man does not slip down the ladder of evolution. Knowledge of causes has greatly increased, and is being followed by a knowledge of cures. As to motive, there is brotherly kindness; moreover the wastefulness of disease is being widely recognized. It is no foolishness to be moved to action by one's purse as well as by one's pity. We must, of course, distinguish between the *theoretical* conquest of a microbic or parasitic disease, and its *practical* conquest, especially when that involves half a continent. But even this will come, as preventive medicine grows.

Similarly, what are called **occupational diseases** will wane away, following those which have been already banished. Men will not much longer acquiesce in modes of work that are obviously injurious, and no one likes to buy articles stained with drops of blood. A well-informed and widespread criticism of expenditure—one of the most powerful of social levers—will increase the number of artists and decrease the number of ivory-carvers, to take two diagrammatic examples.

So, again, with **environmental diseases**, due to unwholesome surroundings, they are bound to disappear as man becomes more and more intolerant of darkness, dirt, and stuffiness in general. Sunlight is the cheapest and most potent of germicides, and fresh air makes for fullness of life. Man has already gone far towards making homes that he can be proud of, but the men of the future will insist on much more. There will be a conspiracy against ugliness and there will be ambitious attempts to beautify the country-side as well as the city. Perhaps there is a risk, indeed, of ambition outrunning taste. *Quis custodiet ipsos custodes?* Who will beautify the minds of the beauty-makers? We already have too many officials.

As to **nutritional diseases**, they have probably increased in fre-

quency and grip since man has become more sophisticated as regards his meals and more sure of a well-spread table. But just as he has gone far in conquering gluttony in solids, so he will continue in subtler ways. One of Benn's 'Sixpennies' on *Nutrition and Dietetics* is enough to show man, for generations yet unborn, how to dine well and yet wisely, how to avoid what Shakespeare called 'life-harming heaviness,' and what another poet called 'the pains of undigested meals ate yesterday.' The consultant slimmer will disappear from the land.

Besides intrusive or microbic, occupational, environmental, and nutritional diseases, there is a fifth kind, more difficult to deal with —the ills our flesh is heir to in a literal sense, the hereditary or inborn ailments and defects that seem to originate as some disturbance in the germ-cells. These **constitutional predispositions to disease,** which usually require some stimulus from food, habits, or surroundings, may be illustrated by certain forms of epilepsy and diabetes, by certain kinds of mental disorder, and by liability to rheumatism. Some disturbance in the balanced working of the ductless glands, such as the thyroid, may be a germinal perturbation to start with, though it does not find its outcrop until adolescence; and since these disabilities begin so early in the life-history, they are naturally more difficult to counter than the modificational disturbances, such as those due to over-eating, over-drinking, over-smoking, and occasionally over-working. For the *individual* who suffers from some constitutional or germinal defect which gives him, let us say, a bias towards rheumatism, it is often possible to do much by counteractive nurture; but what can be done for the *race* if the handicapped individual becomes a parent? In regard to the more serious inborn minuses, what will the men and women of the future say? Unless the trend of humanity changes, they are sure to say that an individual seriously handicapped in his germinal make-up must not be sanctioned as a parent. Only by eugenic methods can these radical defects cease to trouble the race, and even when they disappear no one dare say that new weaknesses may not arise to take their place. It is always safe, however, to put our money on good stock. That way salvation lies.

(4) POSITIVE HEALTH.—The men of the future will have got rid of many of our diseases, but they will also have a firmer grasp of positive health, which implies vigour and initiative. In no marked way will the body have changed; for we know that profitable variations, such as the shortening of our thirty-foot food-canal, gain a foothold with inappreciable slowness. But in days to come man will make more of his body than he has done in recent centuries. He will get rid of grossness and heaviness; he will have less guano in his eyes (as

Emerson cruelly put it) and more oil of joy in his muscles. The unity of the organism will be practically realized, and no one will any longer pretend that he can have a nimble brain along with a sluggish liver.

(5) BETTER EDUCATION.—Man will be better educated, for the pundits will no longer mix up confusedly the three ends of education—the *utilitarian* end, immortalized in the three R's; the *brain-stretching* end, memorialized in Euclid; and the *informative* end, which ought to imply a vivid appreciation of the history of our race, a capacity for exploring clear-headedly and joyously the mysterious universe that is man's home, and a realization of the laws of health and happiness.

Education will be defined as the encouragement of the best that is in us to make the most of the best that is outside of us; and it will be an axiom that the higher values count for most. The superman of the future will be more glad to learn than we are; and he will gird his loins lest he lose the soul in the mind, the mind in the body, and the body in the mud.

(6) SIFTING.—Even more than now will man throw aside the sieve of Natural Selection, but he will be substituting for it many forms of social and rational sifting. He will act on the maxim that a lion's skin is never cheap, for all that is precious must be struggled for. 'Behold the life of ease, it drifts,' as Meredith says.

(7) LOVE AND SEX.—As to love and sex, the men and women of the future, after a vicious parenthesis is over, will not be ashamed to return to Comte's wisdom, and say: 'Between two beings so complex and so diverse as man and woman, the whole of life is not too long to know one another well, and to learn to love one another worthily.' For the outworn sex-taboo, from which we still suffer, will have entirely passed away, and *mauvaise honte* as clouds before the sun. Sex, being better understood, will be more under control, and its urge will be recognized as that of roots, deep in the earth, which are needed for the development of the flowers of love—whence the finest fruits.

(8) FEWER HOMINES, MORE VIRI.—The decline of the birth-rate will no doubt continue, but there will come about what is not yet hinted at for modern times, a decrease in the absolute population of the world, which goes on at present adding to itself at the rate of twelve millions or more every year. It seems to us clear that there are at present too many of us, whence anxieties, miseries, and even wars; but a decrease in the total population will bring about a freshening of the world-atmosphere—fewer *homines* (human beings) and more *viri* (true men).

(9) BREEDING FROM THE BEST.—There is no shutting of our eyes,

except by mental doping, to the grave fact which is technically described as 'the inversion of the birth-rate.' This means that we are breeding more from the worse than from the better. The rate of multiplication is greater among the relatively less fit. This implies that we are contributing to the next generation a larger proportion of the types that are less desirable, biologically and socially. This way *perdition* lies, and the future of our civilization will depend on finding some escape. Nothing is more urgent than bringing brains to bear on the problem of **differential fertility.** There are other factors in progress, but we stand or fall with our wisdom or foolishness in regard to genetic selection, that is, breeding more from the superior than from the inferior stocks.

(10) A WORLD-OUTLOOK.—Once upon a time man's views were those of his village community, and after a while those of his tribe. By and by they became more or less national, even international. The thoughts of men are widened, as Tennyson said, and in the future they will be more cosmopolitan than now. The men and women of the future will ask themselves: What is best for the world? The appreciation of what is good in nationality and in race, as in individuality, will be heightened rather than lowered; but it will be complemented by a world-unity outlook. Even now, as distance disappears before science, and actual contacts increase, there are buds of true cosmopolitanism; the future will see the outcome in flowers and fruit.

(11) SCIENCE FOR LIFE.—What we have been slowly learning from Comte and Spencer, Huxley and Galton, that Science is for Life, and that facing the facts is our first duty in regard to every problem, will be almost second nature to the men and women of the future. Good feeling is doubtless indispensable, but we know where the path leads that is paved with good intentions only. All concrete problems demand for their solution—**more science.**

(12) WISDOM.—And yet the probabilities are that the men of the future will be clearer than we are in regard to the supreme value of *wisdom*—that wisdom which is more than scientific knowledge, that wisdom which has become in the course of millennia enregistered in our social heritage (in folk-ways, morals, standards, institutions, literature, art, and so on)—that wisdom which is, in some partially understood way, engrained in our Primary Unconscious. There are ways which are ever rewarded by survival, success, and progressive evolution, and it is wisdom to follow these clues. There are other ways whose signposts bear the legend—THIS WAY TO DEATH; and some of these signposts are much older than man. They are included amongst our deep inborn prejudices *against* doing this or that.

Given a modicum of wealth and as much health as possible, the men

of the future will define **progress** as an all-round movement towards the fuller embodiment of the True, the Beautiful, and the Good. They will recognize the value of each and every progressive *step*, such as more sunlight, but they will insist that lasting all-round progress, in the sense of a racial uplift, must always include Folk, Work, and Place —all three: the biologist's Organisms, Functionings, and Environments.

These then are some of the features which will mark the men and women of the future, whose creators we are. And when we remember that life has been slowly creeping upwards for over five hundred million years, and that it has made, on the whole, for increased integration, which means control, harmony, unity, we are encouraged by the reflection that this kind of evolution, because more lasting than its disintegrative opposite, is likely to go on. *In hoc signo laboremus.*

What Biology Means to Man

The chief end of science is to make things more intelligible, to discover their laws; but the second end is to learn to control what happens. As Bacon said: *Science is first luciferous* (light-bringing) *and then fructiferous* (fruit-producing). As Comte said: *Knowledge is foresight, and foresight is power.* As Herbert Spencer said: *Science is for life, not life for science.*

It is recognized by all that chemistry and physics have done great things in the service of mankind. What Nature produces in small quantities, such as the internal secretion, or hormone, of the thyroid gland, the ingenious synthetic chemist can now build up artificially as it is required. The abundant free nitrogen of the air can now be fixed by chemical and electrical methods, and used to form ammonium nitrate and the like—steps in the manufacture of 'fertilizers' which increase the world's supply of bread. Modern inventions, such as telegraphy, telephony, wireless, electric light, are largely due to the theoretical discoveries of geniuses like Faraday. Wherever we turn we find chemistry and physics increasing the amenities of life, and if we have our reasonable doubts in regard to the value of synthetic dyes, artificial perfumes, high explosives, and poison gases, we must admit that science, with its discoveries, is not to be blamed for the perversity of man's inventions. A valuable medicine may also serve as a deadly poison, just as aircraft may be used to drop bombs on a sleeping city. But such abuses are not arguments against medicine or against aircraft. They simply reveal the imperfection of man's moral development.

For many years, then, it has been obvious, as regards chemistry and physics, that science is for life, for life more abundantly; but there is less agreement in regard to biology, though that is the general science of living creatures, and should be naturally readiest to ameliorate

human life. The reasons for the lagging appreciation of biology are chiefly the following:

(1) Living creatures are more complex and unpredictable than things and forces, and biological triumphs are correspondingly more difficult.

(2) Biology in the strict sense—*the general science of the nature, continuance, and evolution of life*—is much younger than the physical sciences.

(3) Many striking services due to biological science have been put to the credit of medicine, as if that art were not in great part in modern times an application of biology. Even in ancient days Hippocrates and Galen were great physicians partly because they were great biologists; and, since the days of Pasteur, medicine has become more and more biological. Yet it is plain enough that the traditional appeal to the doctor in any serious illness has been, through the centuries, and still is, an appeal to an honourable art or guild rather than an appeal to a science as such. But to that kind of appeal it has now begun to lead; and medical triumphs, great in themselves, have served as the arresting advertisements of the new idea of appealing to biology for guidance in all the flesh-and-blood difficulties of life. We stand at the beginning of a new era, heralded by Pasteur and Galton, inspired by the idea of applying to the advance and amelioration of life all the relevant resources of biological science. The idea has had, of course, its anticipators, notably Francis Bacon, who spoke of science as ' a rich storehouse for the glory of the Creator and *for the relief of man's estate.*' Or, again, in reference to Salomon's house, which was a prevision of an institute of experimental evolution, he said: ' The end of our foundation is the knowledge of causes and the secret motions of things, to the enlargement of the bounds of human empire and the effecting of all things possible.' These memorable words express our attitude towards biology to-day—an attitude of expectancy and resolution, for the idea is gaining ground that biology can render to human life services which will not be less than those for which we have to thank chemistry and physics.

We must, of course, brush aside the fallacy that the height and depth, the length and breadth of biology are indicated by the familiar study of the amoeba and the yeast plant, the frog and the bean, for these are but the materials conveniently used for discipline in precision and manipulation. We must be thinking rather of the biology so lucidly expounded in *The Science of Life* by Wells, Huxley, and Wells, whose large sale is a sign of the times and a warrant of hope. How much this book would have pleased Professor Julian Huxley's grandfather, who declared in his autobiography the conviction that had grown with his growth and strengthened with his strength that there

was no way out of man's troubles save the resolute facing of the facts as they are.

To face the facts, to understand them, and then, if desired, to control them, that is the aim of the scientific reformer, and in this closing chapter we wish to ask what help is coming from biology. This does not, of course, mean that we do not also seek help from all available quarters — education, psychology, anthropology, sociology, ethics, philosophy, religion, and art.

I. Biology Ameliorates the Struggle for Existence

It is plain enough that the biological sciences may increase the food-supplies of mankind and improve the elementary amenities of human life. For one blade of grass it is easy to get two to grow; 'Marquis' wheat, with its numerous grains and high nutritive value, was evolved by consummate patience in time to help in no small measure to win the war; by ploughing in leguminous weeds, whose root-tubercles are crammed with nitrogen-fixing partner-bacteria, it is possible to make poor soil rich; with due care fisheries can be vastly improved in catch and quality; and the Mendelians tell the poultryman how to rear super-hens, laying over 200 eggs a year, or the farmer how to get herds of better milkers or better fatteners, as he pleases. Isle of Wight disease was ruining the beehives from Ventnor to John o' Groat's, but good will and keen brains discovered the intrusive mite (*Acarapis woodi*) which preys on the bee; and after the knowledge of cause comes the knowledge of cure. Bracken is ruining many of the pasture-lands of Britain, but the discovery of a countering check is now on the horizon.

It is doubtless true that the loaf is no cheaper though wheat is superabundant and of finer quality than ever; it is true that what troubles us just now is not the production of food but the difficulty of selling it; it is true that heavier fish trains from Aberdeen mean more mouths to fill elsewhere; but, on the whole, and taking a long view, it is to the good that biology should increase the food-supply and improve the more elementary amenities of life. Thus it may be that a greater abundance of food will allow of more choice and of a progressive winnowing of occupations. Our first point is that *biology spreads our table, and may help us to spread it more and more wisely.*

II. More Biology Means Less Disease and Better Health

In days now past, yet within the memory of some of us, disease was pictured as a mysterious enemy which suddenly emerged from the darkness and clutched man by the throat, but Pasteur showed that

many diseases were due to intruding microbes, and could be conquered. The discovery of causes leads to the discovery of control, and the list of controllable diseases lengthens every year. If their conquest is in some cases theoretical rather than practical, it is because mankind does not care keenly enough. We think of such microbic diseases as malaria, yellow fever, diphtheria; but the list extends to the mischief done by larger parasites, like the Bilharzia worm, and even to non-microbic and non-parasitic diseases, such as diabetes and cretinism, which are successfully countered by hormone treatment (insulin and thyroxin respectively). No heavier mundane cloud has ever rested on the human race than the disturbances, deteriorations, despair, and painful deaths that follow infection with hookworm, but it is now easy to expel the parasite from man's food-canal and to prevent reinfection. The more biology clears up life-histories and discovers the disseminators of the disease organisms, the easier do preventive measures become, and the ills our flesh is heir to are bound to decrease in proportion to the teaching of sound physiology in schools.

But just as peace is more than the absence of war, so positive health is more than the absence of disease, and here, again, biology contributes notably—with hints as to sound diet, fresh air, sunshine, exercise, habit-forming, careful nurture in the widest sense; and the ideal of healthy-mindedness is a correlate of the vigorous body.

III: Biology as Illumination

Biological counsel is now available in regard to many old-standing problems of mankind; and if people in civilized communities still perish for lack of knowledge, it is largely their own fault. There are problems of adolescence, of habit-forming, of sex, of parentage, of ageing, and so forth, in regard to which biology is already a brightly shining torch. Take, for instance, the importance of play, which has been generally recognized by common sense, but convincingly emphasized by biology. The study of play among animals by Groos and others has made it abundantly clear that play is much more than a safety-valve for overflowing vigour and spirits; it is specific for each type of playing animal, and turns out to be the young form of work. Thus the kittens play at sham hunting, and the lambs at climbing and racing. Play prepares for work. Moreover, the play period is an opportunity for the testing of new departures or variations—the raw materials of possible evolution—which may be ventured before vital responsibilities have become serious. And in play there is also a chance of learning to 'play the game,' as we say, of learning the invaluable lessons of self-subordination, give-and-take, and teamwork. How suggestive this is for mankind, where all the values of

animal playfulness are verified and refined, and where we are also warned of the danger of trying to replace the spontaneity of play by the regulatedness of games—fine as these may be.

In regard to sex, biology has much that is wise to say. Thus our knowledge of the reproductive hormones has made the whole problem of sex more understandable. Yet how often we miss this big truth, that the ascent of life discloses to us the evolution of love, as in birds, and tells us at least half the secret: that of adding aesthetic attractions to the physiological urge, and of adding psychical sympathies until fondness becomes a lasting—it may be lifelong—affection.

IV. The Cultural Value of Biological Science

We have illustrated the practical help that the biological sciences may give us, but it is time to think of another kind of value, not less important, the culture value—to wit, the enrichment of the mind and the development of the spirit of man.

Perhaps there are no fewer than seven ways in which biology contributes to our mental culture, and the first is in giving us pictures that are treasures. What a collection of masterpieces the study of living creatures brings within our reach!

In addition to pictures of thrilling interest, biological study disciplines the aesthetic sense. We pass from easy beauty to difficult beauty, and find in each a joy for ever. We discover that in Wild Nature beauty is almost omnipresent, and that there is naught common on the earth. This is an enrichment of human life, and he loveth best who knoweth most.

A third cultural gift from biological study is the stimulation of interest, for Animate Nature discloses a great drama. It is full of ongoings which angels might desire to look into—ongoings in hedgerow and ant-hill, in shore pool and duck-pond, on mountain and moorland. Everywhere we may find an inexhaustible well of surprises. What a safeguard as well as feast for leisure time!

Then there are the great ideas of biology, which ennoble the mind, especially the idea of the ascent of life, slowly creeping and sometimes quickly leaping, mostly upwards and onwards, for hundreds of millions of years, an idea that has done more than any other for the intellectual emancipation of mankind. And we think also of the central Darwinian idea of the web of life, that nothing lives or dies to itself, but each is a retainer to other parts of Nature.

From the nature of the case the less exact sciences like biology cannot supply the rigorous discipline we get from mathematics and physics, but they have their own brain-stretching value. The world of life is crowded with marks of interrogation. What makes a cell

divide? What is implied in the fertilization of an egg? What is the true inwardness of sex? How does a ferment work? How do migrant birds find their way? How do flowers open and close with the waxing and waning light of day?

There is an even more universal value, that it is only by sojourning in the world of living creatures that we can get the fundamental impressions of growing, multiplying, and developing, of varying, inheriting, and sifting. These are indispensable to a normal mental furnishing, for organisms cannot be safely nurtured on an objective diet of mechanisms only.

We have based the 'culture value' of biology on its disclosure of interesting pictures, things of beauty and dramatic situations, on its gifts of big ideas, brain-stretching problems, and fundamental vital impressions; but mention at least must be made of this seventh value, that Animate Nature educates our sense of wonder, surely one of the saving graces of life. But perhaps we have said enough to suggest the desirability of giving more of our time to biology.

V. Biology as a Basis for Eugenics

To Darwin especially we owe the demonstration of man's affiliation with 'tentative men' and with still humbler creatures. Darwin proved that *Homo sapiens* is an evolved species. But some of those who learned from Darwin were led to the inspiring corollary: 'Not only evolved, but still evolving'; and among these Pasteur and Galton stand foremost. For Pasteur showed how man might strengthen his foothold and extend his empire by conquering disease, while Galton, for a strenuous half-century, continued to ask in season and out of season: 'If man succeeds so well in breeding his domesticated animals and his cultivated plants, why should he not be more successful in breeding himself?' and so he founded **eugenics**—the art of improving the human breed.

One of the oldest ambitions in the world is having a fine family, and eugenics is the application of biological certainties towards this end. Galton never thought of this as merely meaning healthy animals; his eugenic ideal was *mens sana in corpore sano.* He was clear that the mind will, on the whole, thrive best when it has a fine instrument on which to make music, and that the body will, on the whole, thrive best when it is thrilled by a healthy mind. The two sides of the shield are inseparable in the life we know, and eugenics thinks of both—the embodied mind as well as the enminded body.

But Galton himself came of a very distinguished lineage, and thus it was natural that he should think most of the hereditary characteristics—what is engrained in the bone and imbued in the blood.

So he founded eugenics on a scientific study of human heredity, laying emphasis on the mischief of mixing bad seed with good, and on the lasting rewards of careful breeding. The poet Heine once said, half-laughingly, half-bitterly, 'A man cannot be too careful in the selection of his parents,' but from the pathos of this impracticable advice we may be led to let health count for more in the selection of our partners. That way progress lies.

But in the realm of life—the biological realm—secure progress always depends on surroundings and habits as well as on the hereditary endowment of the organism. Organisms, functionings, and environments, these are the three biological co-ordinates corresponding to folk, work, and place in sociology; and if eugenics is to evolve it must have a broader biological basis than even Galton pictured. For the individual, at least, the formative influences in life include surroundings, food, and habits. To eugenics (*eu*, good; *gen*, breeding) there must be added **eutechnics** (*eu*, good; *technic*, work; the improvement of occupations) and **eutopias** (*eu*, good; *topos*, place; the amelioration of environment). Progress will remain piecemeal and insecure unless we recognize the three sides of the biologist's prism—organisms, functionings, and environments, and the indissoluble social trinity of folk, work, and place.

Let us take two or three biological illustrations. In the dark waters of certain caves in Dalmatia and Carinthia there lives the white newt called *Proteus* (q.v.), whose eyes are arrested in development and do not reach the skin. But if Proteus be transferred from the cave darkness to a well-lighted laboratory, it develops pigment in the course of a few weeks and becomes dark-coloured like a common newt. Moreover, if the young stages be reared under red light, the eyes go on growing and developing; they reach the surface and the blind newt receives its sight. How obviously important the environmental factor is—for the individual!

The honey-ants that abound in the Garden of the Gods in Colorado have discovered a peculiar way of storing food for evil days, when the aridity of the country becomes very pronounced. The worker-ants collect sweet juice from certain galls on oak trees, and they feed this to receptive young workers whose crops become more and more distended with the sweetness. These animated honey-pots, as we have called them, must be taken young, and they have been artificially reared by Professor Wheeler, who plied them with abundant maple-sugar. They attach themselves with their claws to the roof of the underground nest, looking like ripe white currants, very sluggish in their movements and unable to reascend if they fall off. There may be 300 in one nest, and they serve as accessible stores, for their instinctive amiability leads them to regurgitate drops of the 'honey-dew' to all

members of the community who care to apply. There is a touch of perfection in the fact that the store of sweetness does not seem to go past the crop region of the honey-pot's food-canal. Because of their bloatedness, the living bags are called 'repletes' or 'rotunds,' and our point is that their efficiency from the community point of view cannot conceal their degenerate life as individuals; which things are a parable! What consolation is there in a eugenic lineage if the creature becomes a rotund?

In the nests of the termites, or white ants (see INDEX), there are often guests—small beetles and some other kinds of insects, which are congenial to their hosts. Some of them provide a much-appreciated exudation; others are simply guests, which make themselves pleasant in some indefinable way. Now these little guests seem to be normal to start with, as is certain in two or three cases that have been studied carefully, but they become in strange ways degenerate. They are among the few exceptions to the rule that Wild Nature is all for health. The posterior body becomes bloated and deformed; the anterior body actually decreases in size; the wings are lost; there is more or less blindness; and the habits of the 'physogasters,' as the degenerates are called, become sluggish. What is the meaning of all this? According to Professor Wheeler, who has studied the matter carefully, the guests degenerate because of the slum conditions of the termitary, which is dark, stuffy, and slightly damp, with narrow passages unsuitable for the guests. Moreover, the guests are victims of over-hospitality, for the termites press them to take too many meals over-rich in carbohydrates. Our point is simply that *heredity is too narrow a basis for an adequate criterion of eugenics*. There is not much consolation in having a good coleopteral pedigree if the individual becomes an obese physogaster!

When we remember that life has been experimenting with itself in Wild Nature for hundreds of millions of years, we cannot but expect that there should be hints for man's encouragement and danger-flags for his warning. Thus we see the success that rewards alert brains and parental care, or again, the penalties imposed on parasitism and on extreme division of labour. We cannot be so anthropocentric or self-centred as to suppose that the prizes are awarded or the penalties imposed *in order that* man may be instructed, but it is a gratuitous error in the opposite direction to refuse to learn from the lessons of the long-drawn-out drama of organic life. Our point is that the eugenist may be encouraged and warned, not only by the study of human heredity, but by all the subtle ways in which Animate Nature has wrought out its exuberance of evolving life. Thus man may learn from birds not to stop singing when the honey-moon is over.

VI. Biology Contributes to Ethics

As we have already hinted, biology may strengthen man's hands in his ethical endeavour. We hear sometimes about the evolution of ethics, an interesting subject; but how seldom we hear of the ethics of evolution. Yet if Nature teaches man anything, it is the value of struggle, the danger of the unlit lamp and the ungirt loin. A lion's skin is never cheap, and good things have to be gained and kept by effort. Yet we hear far too much about the cruder forms of the struggle for existence—'Nature red in tooth and claw,' 'the vast gladiatorial show,' 'the Hobbesian warfare of each against all, the stampede in which each is for himself, and extinction takes the hindmost'—and far too little of the struggle that secures for the offspring a good send-off in life, the time and energy expended in activities which are other-regarding, not self-indulgent. It was not by chance that the highest class of animals, to which we belong zoologically, was given the name of mammals or motherers. Man must struggle or else retrogress; but he may rise above the cruder forms of the struggle for existence to a culture of existence, from a life-and-death competitive jostling around the platter of subsistence to an ennobling endeavour after well-being. That way progress lies, and biology joins hands with other educative and moralizing influences in pointing the way.

What is human progress? It has three pre-conditions: (1) a high standard of positive health, without which all is vanity; (2) a reasonable share in reasonably distributed wealth, which means enough command of energies to ensure some leisure and change, some beauty and comfort; and (3) a social system in which there is rational selection, such that superiority receives the rewards it has earned, and inferiority the penalties it deserves, where the arrangements in any case are not such that it is as well to be inferior as to be superior.

Given these three pre-conditions in high measure of realization—an ideal still remote—true progress consists in a balanced all-round movement towards a fuller embodiment of the true, the beautiful, and the good. But what has biology to do with this? Much more, we answer, than appears at first sight.

Thus we note that Wild Nature—that is, Nature apart from man's interferences—is all for health (see p. 1460). If we define diseases as disintegrative and deteriorative disturbances of the balanced harmony of health, there are almost no diseases in Wild Nature. There are plenty of parasites, but they usually establish a *modus vivendi* with their hosts; there is abundant infection with microbes, but some years ago the late Sir E. Ray Lankester said that he was sure of only one microbic *disease* in Nature—a bacterial malady of sand-hoppers. We must not press the truth too hard, but, in any case, disease is

very rare in Wild Nature, and exuberant positive health is characteristic. Now, who can exaggerate the value of health? It is halfway to happiness; it frees us from handicaps and urges us to higher things; it unifies our being which disease distracts and disrupts; it makes for efficiency; it tends to healthy-mindedness; and it is an extraordinarily sensitive touchstone of moral conduct. More and more every year, biology offers us better health.

Why, then, is man, a creature of reasonable discourse, with all his science and other forms of garnered wisdom, so liable to diseases and so prone to acquiesce in sub-health? He never had better advice than he has to-day, never wiser and more skilful physicians, yet his standard of health remains low.

Part of the answer to this painful question may be found in the following facts: that *Homo sapiens* is a new-comer species, still very imperfectly adapted; that he finds himself in a complex and changeful social environment with which it is difficult to keep pace; that he permits not only lower appetites but high ambitions to override the claims of health; that he allows undesirable types to be sheltered by society, in which there is too little hygienic sifting; that he breeds carelessly, and so forth. But another part of the answer is that man is only beginning to apply biology to the everyday problems of life, only beginning to learn to think biologically.

And not only is Wild Nature all for health, it shows an almost omnipresent beauty, and proclaims the open secret that much of organic beauty is an expression of healthy harmonious living, and much the expression of strenuous endeavour, and much the outcome of a wholesome mind irradiating the flesh. As the poet said: 'Her temple face was chiselled from within.' We may even go the length of saying that there are trends towards truth in Animate Nature, for there is survival value in alertness, clear-headedness, and the habit of facing the facts—habits of mind which are more than adumbrated in the higher animals.

Huxley said that man at his best must set his face against Nature and struggle in the opposite direction. But this was a misunderstanding, for man, even at his best, has much to learn from the self-subordination, the other-regarding devotion, the kin-loyalty, the primary virtues of courage and gentleness that biology discerns in those animals on which Nature has most emphatically placed her sign of approval.

VII. Biology Contributes to Philosophy

We are all philosophers in the sense that we try to get an all-round or synoptic view of the world and our place in it; and the seventh

service that biology is prepared to offer is a contribution to a sound philosophy. Tens of thousands of thoughtful people have tried of late to fit into their philosophy what Sir James Jeans has told them about the mysterious universe, and our point is that they must do the same for what the biologist is willing to tell them about the more and more intelligible, but still fundamentally mysterious, world of life. We have to incorporate into our philosophy the great facts regarding the ascent of life, its manifoldness and beauty, its insurgence and purposiveness, the increasing emancipation of mind in the course of evolution, the solidarity of man with the rest of creation, and yet his not less striking apartness. We must not only see man in the light of evolution, we must see evolution in the light of man—for he seems to be an instalment of the realization of part of the purpose that lies behind it all. The long-drawn-out process has been such that it led to us!

Two cautions in conclusion: (*a*) Just as biology in a sense transcends physics and chemistry, so sociology transcends biology, and, including ethics, is the final court of appeal; (*b*) it must not be supposed that any one can at once appreciate the whole gamut of biology, but what every one can do for himself, or for those in his care, is to begin thinking biologically—and what does that mean? It means thinking of everything in the light of life—life in evolution, in terms of organisms, functionings, environments.

Thus our proposition is that biological science can render mankind seven great services:

I. It can spread our table and increase the amenities of life, ameliorating the struggle for existence.
II. It can conquer disease and help towards an increase of positive health.
III. It can offer good counsel to help man to meet some of the perennial problems of life.
IV. It has a manifold cultural value.
V. It affords a basis for eugenics.
VI. It is full of ethical suggestiveness.
VII. It has contributions to make towards a sound philosophy.

Therefore let us have more biology.

Illustrations of Man's Achievements

To the biologist man is the highest organism when considered in reference to purely biological standards, such as the differentiation and integration of the body, the complexity of the nervous system,

and the range of adjustment to a great variety of conditions. Even if we take the hand, which is a very *generalized* hand as compared with, say, a bat's, an aye-aye's, a mole's, it has a touch of perfection in its extraordinary adjustability to all sorts of functions.

But while the biologist, looking at man biologically, must place him at the top of the tree, he must confirm this by **psycho-biological** considerations, when he takes account of man's power of experimenting with general ideas (Reason, as transcending Intelligence), of language (as distinguished from having words), and of morals (controlling his conduct in reference to ideals). If man is the crown of creation—the climax of Organic Evolution—we must envisage Animate Nature in the light of man, for the long-drawn-out process has been such that it has led to *him*, and this is our apology for saying just a little in regard to man's achievements.

(1) SCIENCE.—Some of the higher animals, like monkeys, elephants, dogs, and horses, find out about things and build up knowledge, which they remember and can recall. Often they modify their impulsive behaviour in the light of what they have learned. Here may be discerned the anticipations of science.

But science in the strict sense is a body of criticized descriptive knowledge, based on observation and experiment, formulated in the tersest and simplest **laws** (shorthand summations of uniformities). Science is descriptive knowledge, telling us what things are, how they continue, and how they came to be; it does not inquire into purposes or ultimates; it asks 'how?' not 'why?' It seldom gets us beyond an equation, which enables us to say: 'If this, then that.' It is not the only kind of knowledge, but it includes all precise descriptive knowledge that is verifiable by all normally constituted minds that can use the methods. But science is not as yet at a uniform level of precision.

The five great sciences are Chemistry, Physics, Biology, Psychology, and Sociology; but Chemistry and Physics have fused and so have Biology and Psychology. Thus there are three great sciences, dealing respectively with the domain of things, the realm of organisms, and the kingdom of man. Mathematics, Statistics, and Logic are mainly *methods*. In many cases there are compound sciences, several throwing light on our subject, e.g. Geology and Geography. Very conspicuous are applications of science, as in Engineering, Agriculture, Education, Medicine, all based on the 'pure sciences.'

(2) MASTERY OF NATURE.—Our early ancestors had relatively little power of harnessing the forces of Nature to their purposes. But gradually, while remaining in the giant's grip, man has been able to make Nature obey him. He can divert the lightning, and indirectly he can make it carry his messages and pull his trolley-car. Wind

and wave and waterfall, he makes them all work for him. The secret motions within the dust, they do him service. Out of the thin air he coerces 'fertilizers,' and thus gets more wheat than he can make into bread. Every year sees some disease conquered, and the wise have begun to influence the generations yet unborn. So we might continue for many pages, proud in man's record of mastery to which no one can set a limit. That it may be used for evil as well as for good is the fault of man's moral nature, not of his mastery nor of the knowledge on which it is based.

Many great steps in mastering Nature were based on empirical lore without much science behind it. Thus there was first-rate farming long before there was any Agricultural Chemistry, and similarly on many other lines. But the truth is that most of the more remarkable successes have been due to the growth of science as distinguished from lore, and it is an instructive fact that we must trace to advances in pure science most of the big practical inventions that have added so much to the amenity of life in modern times—telegraphy, telephony, wireless, electrical transport, and the like. The inventor is in most cases on the shoulders of the high-brow *discoverer*.

(3) RELIGION.—Religion, arising at many times and in diverse manners, includes all man's emotional, practical, and intellectual appeals to the unseen or mystical, when he finds himself straining at the end of his powers. He may praise or pray (emotional), he may offer sacrifice or build temples (practical), or he may construct a theory or creed (intellectual), or his appeal may have these three sides at once. The limits which baffle man and lead him to a religious activity of some sort have varied and still vary greatly. Thus the cup of joy or sorrow may be too full to hold without some expression of religious feeling; or man may find himself balked practically when he has done all that mortal man can think of; or he may bow overawed in face of the mysteriousness of Nature and his place in it. The expressions of the religious mood may be primitive, hardly rising above an appeal to magic or relapsing to that ancient system of belief, but they are sometimes so noble that they must be ranked among man's high achievements. On the intellectual side they often join hands with philosophy, on the emotional side with art, on the practical side with the endeavour after goodness; but the word 'religion' is misused if it does not imply a recognition of the mystical or spiritual. In some way and in some degree the religious man is always sending out tendrils towards the Supreme Reality; which he usually names to himself as GOD.

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